Canada. Dept. of Railways
and Canals
General specifications
for steel bridges and
viaducts

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TORONTO

DEPARTMENT OF RAILWAYS AND CANALS

GENERAL SPECIFICATIONS

FOR

STEEL BRIDGES AND VIADUCTS

ALL PREVIOUS SPECIFICATIONS ANNULLED

1905

OTTAWA
GOVERNMENT PRINTING BUREAU
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DEPARTMENT OF RAILWAYS AND CANALS

GENERAL SPECIFICATIONS

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SUBSTRUCTURES OF MASONRY AND CONCRETE FOUNDATIONS.

For all structures, requiring the approval of the Department of Railways and Canals, the following general conditions will be observed, and are the minimum requirements for substructures :—

Soundings and borings

1. The nature and character of the material, upon which the structure is to rest, must be determined by soundings and borings, with the usual appliances, or, if necessary, with the diamond drill. Upon the information obtained the type of foundation that will be approved can be determined.

Foundations of caissons, or cribs, sunk by dredging, or other method of excavation, below the bed of river ; before filling the caissons the Engineer may require additional borings within the cribs.

Pneumatic foundations

2. Foundations in a depth of 20 feet of water, or more, difficult to be kept unwatered, and where there exists the slightest uncertainty with regard to the material upon which the structure is to ultimately rest, or the formations of material beneath the proposed foundation seat, to secure a proper foundation for the piers and abutments of the bridge the pneumatic process will preferably be required.

3. Pneumatic caissons may be constructed of timber or steel, if of timber any sound timber may enter into their construction. They shall have excess of strength, be properly bolted and the pneumatic chamber

thoroughly braced. The dimensions of caissons both as to base and height will depend upon the character of the material upon which they will finally rest and the depth to which they will be sunk.

Detail plans of the caisson must be submitted for, and receive, the approval of the Engineer before the work is commenced.

In order to minimize the dangers to the workers in caissons all appliances and machinery connected with the pneumatic work shall be of the most modern type and the best procurable for the purpose.

Bearing pressure.

4. The permissible bearing pressure, per square foot of foundation, will vary with the character of material upon which it is proposed the structure will rest.

The pressure, on pile foundations, upon each pile will be determined in a similar manner.

Piles.

5. In pile foundations the piles will be generally 12 inches by 12 inches at the head and at least 8 inches by 8 inches at the small end, for piles 30 feet and less in length; for greater lengths the piles may be reduced in diameter 1 inch for every additional 10 feet to a minimum diameter of 6 inches.

The piles will be of timber which will stand the impact of the hammer, straight sound and of live wood. They will be ringed for driving and shod if directed by the Engineer. They will be driven until they do not sink ½-inch under the blow of a hammer of one ton weight falling 25 feet.

Area of pile foundation.

6. The areas of pile foundations of piers and abutments will be excavated or dredged to a depth determined by the Engineer.

The grade of the bottom of such foundations will be 1 foot below the top of piles and before the concrete is deposited the top of piles will be cleared of all material.

Platforms on piles.

7. Pile foundations with platforms; the piles will be sawn off at the height directed by the Engineer and capped by 12 inches by 12 inches timbers, upon which shall be laid a platform of timbers of the same dimensions, both will be properly secured by drift bolts of 22 inches by ¾-inch in size. Spaces between piles will be filled with concrete rammed to level of the surface of heads before the timbers are laid and the spaces between timbers will be filled with concrete rammed.

Pile foundations with sheet piling.

8. Pile foundations, which are inclosed with water-tight sheet piling, will be excavated or dredged to the depth directed by the Engineer and the piles driven after the excavation has been made. They will be sawn off at least 2 feet below lowest water. The sheet piling will be sawn off one foot below lowest water. The space between the piles and between them and the sheet piling will be filled with well-rammed and tamped concrete.

Foundation bed cleaned

9. When the structure is founded upon rock the latter must be cleaned of all dirt, earth, loose rock, and if necessary levelled or stepped, to receive the concrete or masonry.

Depth of foundation.

10. Material such as hard pan, gravel, clay, cemented sand which will withstand the permissible bearing pressure without piling, the foundation will be excavated to a depth as directed by the Engineer and levelled.

Pits and trenches.

11. The pits and trenches of foundations will be kept free from material injurious to the character of the work, and kept unwatered during the depositing of concrete and building of masonry or for such time as the Engineer may direct.

Filling around structure.

12. Filling around masonry or concrete structures, will be by layers of earth well tamped.

Rip rapped.

13. Structures upon bottoms liable to scour must be immediately rip rapped.

Caissons upon bed of river.

14. Bottomless timber caissons which rest upon the bed of river, when it forms a suitable foundation, the bed shall be levelled off before sinking the caisson, and by shaping the timbers at the base of caisson allow for all irregularities of surface.

Caissons upon piles.

15. When the caissons rest upon piles the bed of the river will be dredged and soft material removed, the piles will be driven and sawn off at the same level. The timber caissons will extend to within 3 feet of lowest water.

Bottomless caissons filled with concrete.

16. Bottomless caissons, when partially filled with concrete deposited through water (to seal the bottom before unwatering), if there are vacant spaces between the foundation bed and the base of crib, subjecting the first layers of concrete to washing; around the lower side, canvas will be secured to the timbers and project over the bottom, bags of concrete will be placed upon the canvas, and divers will fit them well into angles and apertures between the crib and bottom so that all scour will be prevented; other effective means may be used which will secure perfectly still water in the caisson.

Depth of concrete laid under water.

17. The proportional depths in caissons or cribs, of concrete deposited under the water to seal the bottom, and that laid after the cribs have been unwatered shall be determined by the Engineer. Divers shall be sent down to pack and fill all angles and spaces around timbers with the concrete. Caissons will be designed to resist the pressure of water which the depth below water level, unwatered, will produce.

Concrete tested with drill.

18. In concrete deposited, in caissons, through the water, if required, when it has properly set, a diamond or other drill, will be used to obtain a core, and to determine the character of the concrete before the approval of the foundation.

19. There shall be a space of at least 2 feet all around between the inner face of timbers and the base of masonry.

20. If a crib is built perpendicular, in height, the batter of the masonry of pier produced must fall within the crib.

PORTLAND CEMENT.

Quality.

21. The cement must be of the best quality of Portland cement, fine ground, dry, free from lumps, preferably packed in barrels lined with tarred paper.

Chemical analysis.

22. It shall have a chemical analysis, approved by the Engineer and determined by the tests of chemists of his selection, and shall not contain more than 1·75 per cent of anhydrous sulphuric acid (SO_3), nor more than 4 per cent of magnesia $(M^g O)$.

It shall be fresh and shall not have lost strength through age, but not of that degree of freshness to be hot or quick setting.

23. Cement must be freshly ground to a degree of fineness that 95 per cent, by weight, will pass through a standard sieve of 10,000 meshes to the square inch and 75 per cent, by weight, through a sieve of 40,000 meshes to the square inch.

Set.

24. It shall not develop initial set in less than thirty minutes, but will develop hard set in not less than one hour nor more than ten hours.

Pats

25. Neat cement pats for testing will be mixed upon glass for five minutes with 20 per cent of water, by weight. Each pat will be about 3 inches in diameter and ½-inch thick at centre and tapered to a thin edge.

Pats in air, water and steam tests shall remain hard and firm; they shall show no sign of checking, swelling, blowing, cracking or warping and will have a blue gray colour free from yellow spots and blotches.

Vicat needle test.

26. The cement, in pats, by the Vicat needle, will have developed initial set when the pat will withstand without indention the wire of 1/12-inch diameter loaded with a weight of ¼ pound, and will have developed hard set when the pat will withstand without indention the wire of 1/24-inch diameter loaded with a weight of 1 pound.

Briquettes

27. Briquettes will be of standard form with a minimum section of one square inch at the centre. The mortar will be pressed into the moulds with the thumbs and smoothed off on both sides with the trowel. The briquettes will be kept in a damp atmosphere 63° F. to 68° F. for twenty-four hours, and submerged in water maintained at the same temperature and remain therein until broken. The test room for the various operations will be maintained at the same temperature.

NEAT CEMENT TESTS.

28. In standard tests the tensile strength, in briquettes of neat cement, shall be :

Tensile strength.

	Lbs. per Sq. In.
One day air and six days water..	450
One day air and 27 days water..	600

The increase from seven to twenty-eight days shall not be less than seventeen and one-half per cent.

CEMENT AND SAND TESTS.

29. The proportion of water used will be such as the mixture is thoroughly wetted but no superfluous water when the mortar is pressed into the mould. The briquettes, the method of mixing, filling the moulds and their operations will be the same as neat cement tests.

Mixing and filling briquettes.

30. The tensile strength shall, in briquettes of one part cement to three parts sand, by weight, be :

Tensile strength.

	Lbs. per Sq. In.
One day air and six days water..	150
One day air and twenty-seven days water..	220

The increase from seven to twenty-eight days will not be less than twenty-five per cent.

31. The sand for standard tests will be of crushed quartz, which will pass through a twenty mesh sieve and be retained upon a thirty mesh sieve.

Sand for tests.

Ordinary sand, when used in briquettes, will pass through a sieve of twenty meshes to the lineal inch and be retained upon one of twenty-eight meshes.

32. Sand for concrete and mortar must be clean, angular, large grained, sharp and not contain more than five per cent of mica, clay, loam or other impurities.

Sand for mortar.

CONCRETE.

33. Concrete will be composed of cement, sand and broken stone, or gravel, mixed with clean water in the proportions the Engineer may direct.

Composition of concrete.

34. Broken stones for concrete will be, preferably, machine broken limestone or other hard stone. It shall be clean and screened and of such dimensions as the Engineer may direct.

Broken stone.

35. Gravel will be of assorted sizes, screened and washed entirely free from clay, loam or foreign matter, and also clear of slime, scale or mould.

Gravel.

36. The concrete will be mixed in cubical mixers, or such mixer the Engineer may approve.

Concrete mixing.

37. When concrete is permitted, in small quantities up to 1000 cubic yards and in batches, not to exceed one cubic yard, to be mixed by hand a platform shall be used, it shall be thoroughly turned so that every stone will be coated with mortar. The cement and sand shall be first thoroughly mixed dry to an uniform colour, with not less than four turns of the shovel, and that quantity of water added which will enable the mortar to remain firm upon a trowel and the mixture then turned four times. The stones must be well moistened before being mixed with the mortar.

Boulder concrete.

38. Boulder or 'one man stone concrete'; the stones or boulders must be thoroughly cleaned and moistened before being deposited in the work. They shall not be laid closer to the face of structure nor to each other than 12 inches and shall be thoroughly packed with the concrete.

39. In piers and walls exceeding 6 feet in thickness stones may be used not over 2 feet in thickness, the stones in the aggregate will not exceed twenty-five per cent of the entire mass.

Deposit of concrete.

40. Concrete shall be deposited immediately after mixing, and before an intitial set commences, in even layers of not over 9 inches in thickness; it shall be well rammed until the mortar flushes to the top, and will be followed by the next course before set has taken place.

Concrete, which has taken set, shall be cleaned, roughened and a layer of mortar spread, or grout flushed, over it before the next course is deposited. Fresh laid concrete will be covered and protected from the sun; before masonry is laid upon it there will be twenty-four hours allowed for set.

Deposit of concrete under water with buckets.

41. Concrete, when permitted to be laid under water, and only in still water, may be deposited in a covered bucket or box of about two cubic yards capacity, of approved pattern and every precaution shall be taken to protect the concrete from the action of the water. Particular care will be taken that the bucket is not dumped before reaching the bottom.

42. Concrete, deposited through the water, shall be particularly rich in cement as there is considerable wash of cement from the sand and broken stone in depositing.

Deposit of concrete by tubes.

43. Concrete may be deposited under water through a water-tight telescopic tube, or a telescopic tube bucket with an automatic hinged bottom, reaching to the surface upon which the concrete is to be deposited, and in layers not exceeding 2 feet in thickness unless otherwise ordered by the Engineer.

44. The concrete must be fed, to a tube without bucket bottom, continuously from a hopper on top of it which shall be at least double the capacity of the tube.

The tube will be kept full of concrete until stoppage of use, or when required to raise it over some obstacle, or out of the water. In case the tube becomes full, or partially full, of water it shall be lifted slightly and the water expelled by suddenly filling it with concrete.

45. In the depositing of small quantities of concrete, where the tube is permitted to be kept full of concrete by wheel barrows, when the tube is partially, or completely filled with water, an amount of cement equal to twenty-five per cent of the volume of water in the tube shall be added to the concrete used in filling the tube.

Proportions for concrete.

46. Suggested proportions for concrete by volume and measured loose.

Component Parts	Portland Cement.	Sand.	Stone.	Diameter of stone in inches.
Foundations, first foot, at bottom	1	2	5	2
" footing courses	1	2½	6	2½
" interior	1	3	7	3
Bottomless caissons, filled through water	1	2	4	2
" " sealing bottom	1	2	3	1½
Caissons, pneumatic chamber	1	2½	5	2
" sealing 2 feet at bottom	1	2	3	[illegible]
Backing, large structures and walls	1	2½	6	[illegible]
Abutments, piers and spandrel	1	3	5	[illegible]
Arches	1	2	5	1
Coping, parapets, and light piers	1	2	4	1

CONCRETE STRUCTURES.

Forms of concrete structures

47. For concrete structures forms will be constructed of sufficient stability to maintain form and outline. On exposed surfaces they will be built of dressed and matched lumber.

Forms will not be removed for forty-eight hours, or such period of time as the Engineer may deem necessary.

Facing of mortar

48. Exposed surfaces will have a facing of mortar deposited with the layers of concrete which will be well spaded and tamped with the facing.

Provision for expansion

49. For heavy concrete walls provision will be made for expansion in about every 40 feet, in light walls in every 20 feet.

Water proofing

50. Concrete abutments, arches, retaining walls will be, preferably, thoroughly water-proofed. After the concrete is dry it will receive a coat of asphalt cut with naptha. This surface will then be covered with an asphalt mastic consisting of one part mastic to four of sand which will be thoroughly tamped and pressed into place and smoothed off with hot tamping irons.

UNIT STRESSES FOR CONCRETE STEEL REINFORCED STRUCTURES.

	Pounds.
Modulus of elasticity of concrete..	1,500,000
Modulus of elasticity of steel..	30,000,000

51. In maximum compression—

	Lbs. per Sq. In.
In arches for electric car and highway bridges, exclusive of temperature stresses..	400
Including stresses due to 40° F. variation in temperature..	500
In arches for railway bridges, exclusive of temperature stresses..	300
Including stresses due to 40° F. variation in temperature..	400
Maximum tension on concrete..	0
Maximum shear on concrete..	50

Factor of safety. 52. Highway and electric car bridge substructures shall have at least a factor of safety of four in thirty days. Railway bridge substructures shall have at least a factor of safety of five in thirty days.

53. Maximum stress on steel—

Steel ribs. Steel ribs in arches under a stress not exceeding 15,000 lbs. per square inch must assume the maximum bending moment of the arch without assistance from the concrete.

Transverse stresses. In structures subject to transverse stresses the steel shall be assumed to take the entire tensile stress without aid from the concrete. The area of reinforced steel with an elastic limit of 30,000 pounds per square inch will be about one per cent of the area of the concrete.

Compression. 54. In walls and posts subject to compression only no allowance shall be made for the strength of the imbedded steel.

MASONRY.

55. The stones shall be of a sound and durable nature free from dries, shakes or flaws, and of a description which will not be affected by the weather.

Character of masonry. The masonry, generally, shall be rock-faced ashlar laid in courses not exceeding 36 inches nor less than 15 inches in height. The rock face will not project more than 3 inches beyond the face or draft lines of the stones and without hollow faces. There will be a chisel draft of, at least, 2 inches at corners and batter lines.

56. Coping stones, chamfers, arrises and cutwaters shall be chisel-dressed.

57. Stretchers shall not be more than 6 feet in length nor less than 4 feet, the upper and lower beds to be of a depth not less than 1½ times the height of course when the course is less than 24 inches rise. Stretchers.

58. Headers shall be built, in each course, not more than 6 feet apart and arranged so that they will be equally distributed over the faces of the structure, but in no case shall a header come over a joint nor a joint over a header. Their length, in the face of work, shall not be less than 24 inches. They will have a depth in the wall of at least 4 feet and not less than 2½ times their rise, and will have the dimensions through the wall which they have in the face.

Walls, 6 feet and under, and piers 7 feet and under, in thickness, will have the headers extend through the whole structure, in thicker pier there will be a header extending between the face headers.

59. The stones must be square jointed and laid on their natural beds, the largest bed down; the beds well dressed, parallel and true and as large as stones will admit of. Beds and joints.

The bed and sides of stone will be cut and dressed so as to form joints not exceeding ½-inch in thickness; the beds throughout, and the side or vertical joints, shall be dressed close for at least 12 inches back from the face and 1 to 4 inches for the remaining length of stone, and shall break not less than 12 inches with the joints in the course below.

60. Stones whose joint surfaces may have hollows not more than 6 inches across, provided these holes do not exceed one-third of the joint surface required and that they are not nearer than 3 inches from the edge of joint, may not be excluded. Hollows in joints.

61. Coping stones, parapets, bridge seats, arrises and cutwaters shall be accurately cut, either chisel-dressed or bush-hammered. Stones to be chisel dressed.

62. Stone must be moistened before being laid and before the succeeding course is built. Stones shall be cleaned and fitted to proper bearing and bed, then raised and a full mortar bed spread, and shall be brought to a firm level bed without the use of spalls and pinners. Stones which have been moved after mortar has set shall be taken up and reset in fresh mortar. Hammering on stone will not be allowed after mortar has set. Each course shall be flushed with mortar before the next course is laid. Stones, how laid.

63. The coping of piers and abutments shall be the best stone found in the quarry and shall be not less than 24 inches in vertical height for long spans. The stones shall be dressed square throughout for ½-inch joints. Coping.

64. All masonry shall be pointed; the joints shall be freed of mortar to the depth of 1½ inches and refilled, they shall be throughly moistened before pointing, and the mortar kept moist during the day the pointing is done. Pointing.

Cut-waters.

65. The stones in cut-waters shall have the beds and vertical joints dressed back the full length of the stone to a joint of ¼ inch. They shall have an area of bed of not less than 6 square feet.

Countersunk cramps will be fitted into each course and fastened with bolts through 1½ courses of masonry and the holes filled with cement grout. The backing of cutwaters shall be the same thickness as the face-stone and dressed to ½-inch joints.

Stone backing.

66. Backing of Stone.—The beds of all backing must be picked off to ½-inch joints and the stones shall be not less than ½ the thickness of course, nor less than 8 inches in depth. When the vertical joints average more than 2 inches they must be hammered off. The stones will be laid in full mortar beds and shall break joint and bond at least 10 inches and must be in contact with surrounding stones. The spaces, between the stones, which shall be not over 6 inches, will be filled with spalls, small stone laid flat and fully flushed with mortar. The stone shall have an area of bed of at least 3 square feet. No grout will be used except ordered by the Engineer.

Concrete backing.

67. Backing of Concrete.—The concrete shall be deposited in layers of 9 inches, and rammed, care being taken to pack thoroughly about face stones. At each course it shall be well levelled, all holes and cavities run up full and the whole flushed with mortar.

Mortar, how mixed.

68. Mortars.—The cement and sand will be mixed dry in a box and sufficient clean water added, in such a manner as not to wash out the cement, to make a stiff paste which shall be well worked or mixed and used at once. No mortar which has not been used shall be remixed.

Proportions for mortar.

69. Mortar proportions shall be in parts :

	Portland Cement	Sand.
Ordinary beds and joints..	1	3
Plastering moulds..	1	2
Beds and joints of cutwater, coping and pointing..	1	1

Dimensions of piers.

70. The dimensions of piers shall generally, at the coping, be proportioned to the width of superstructure and dimensions of bed plates. The batter shall usually be ½-inch to 1 foot. The batter of cut water will depend upon the local conditions of ice, &c., &c.

STEEL SUPERSTRUCTURES.

Stress sheets.

71. Complete stress sheets and general plans of structure shall be submitted with the tenders.

The stress sheet will be 18 inches by 23 inches in dimensions, upon which will be drawn a diagram of the truss and lateral systems. The general dimensions and data upon which calculations are made, and all pertinent information will be legibly denoted.

Below the diagram there will be a tabulated form, enumerating members, stresses from live and dead loads, impact increment, the length of compression members in inches, the radius of gyration, with a sketch showing clearly the make up of the member, unit stresses, formation of shapes of sections, areas required and net areas. The bending moments, shears, moments of resistance and net areas of floor beams and stringers will be stated.

Inclusive of the above information the stress sheets of swing bridges will have tabulated the stresses produced by the five cases ; the combination of stresses, stresses upon which sections are proportioned, reactions, stresses upon members of turntables.

General drawings.

72. For approval by the engineer in addition to the stress sheet there will be submitted a general drawing, preferable dimensions 23 inches by 36 inches, showing elevations, plans, cross sections, and the shapes of various member figured upon member. Drawing of swing bridges will show type of turntable and sketch design of all operating machinery.

Signs for compression and tension.

73. The plus + sign must, in every case, be used for compression and the minus — for tension stresses.

Detail and working drawings.

74. In bridges, erected by the Department of Railways and Canals, after the stress sheets have been approved and before the construction of any part of the structure shall be proceeded with, complete working drawings shall be furnished in duplicate, showing all details of construction which shall conform to the general design, shapes and dimensions shown on the stress sheets, and general plans and to all the conditions of this specification. These drawings shall be approved by the Engineer before the work of construction is proceeded with.

Dead weights.

75. The dead weights used for calculating stresses must not be less than the actual weight of structure when completed.

Approval of plans.

76. Work done, before the approval of the drawings and plans, will be at the Contractor's risk.

Material in superstructure.

77. All parts of the structure, except ties, guard timbers, joists and floor plank, shall be a medium acid, or basic, open-hearth steel, except rivets and bolts which will be soft acid or basic open-hearth steel, and buckled plates medium, or soft, open-hearth steel.

Steel or cast-iron will be used in swing bridges, bed plates, and other purposes. Cast steel being preferred for all important castings.

HIGHWAY BRIDGES.

Headroom.

78. All through bridges shall have a clear headroom of at least 14 feet and a clear width to be specified by the Engineer.

Floors, joists of wood.

79. First—The joists, when of wood, will be creosoted, when specified before tenders are made out, they will be laid longitudinally, with

not over 2 feet centres. They shall not be less than 3 inches wide, 12 inches deep, and will vary in dimensions according to the length of panel and loading specified.

The joists shall have full bearings on the floor beams lapping by the joist of next panel; when directed by the Engineer there will be ½-inch air space, and they will be fastened to each other by ⅝-inch bolts or lag screws; they will also be bolted to the floor beams, allowance being made for expansion and contraction.

Floor plank for wooden joists of not over 2 feet centres will not be less than 3 inches thick, and from 8 to 10 inches wide, and laid with ¼-inch openings, and with the heart side down.

Floors: steel stringers.

80. Second.—The floor, when directed by the Engineer, will be laid on steel stringers, spaced not more than 3 feet 6 inches centres, under the wagon ways.

Electric railway stringers and ties.

81. There will be especial stringers under the rails of street railway crossings of highway bridges.

The ties, upon these stringers will not be less than 6 inches and 8 feet in length; they shall be spaced 10 inches apart and covered with plank not less than 2 inches thick.

Nailing strips, when there is not a paved floor, will be secured to stringers by ⅝-inch bolts.

Floor plank.

82. The floor planks will be of white or southern pine, 4 inches thick, and laid with ¼-inch openings. They will be sized to a uniform thickness if a wearing surface is specified.

The wearing or top floor, when used, shall be of white oak, elm or spruce, as directed, not less than 1½ inches thick, and not over 8 inches wide. They will be dressed on the bottom side to an even surface.

Sidewalk floors will be of plank, 2 inches thick and 6 inches wide, and dressed on top to thickness. Note clause 86.

Spikes and nails.

83. The under flooring shall be fastened to the nailing pieces by wrought spikes, 7 inches by 7/16-inch, holes to be bored at the ends of all plank 1/16-inch smaller than the spikes.

The top flooring shall be fastened by sixty penny nails of best quality. The sidewalk plank will be fastened with 30 penny nails.

Wheel guards.

84. Wheel guard timbers, which shall extend over piers and abutments, not less than 4 inches by 6 inches, in dimensions, with a 6-inch. lap joint over riser-blocks, shall be bolted to the floor on each side of wagon-way, with a clearance of at least 8 inches between inner edge of guard timbers, and inner lines of truss or sidewalk.

Riser blocks.

85. The riser blocks shall be 1 foot in length by 6 inches by 2 inches, and shall be spiked to the floor by 4½-inch spikes. They shall be spaced not more than 7-feet centres. The guard rail will be bolted to the floor through each block.

86. The inner edge of guard rails or of sidewalks within trusses will, when specified, be protected by an angle iron 3 inches by 3 inches by ⅜-inch fastened by iron screws or countersunk spikes.

87. When the floor is to be paved the buckled plates will be at least ⅜-inch thick and there shall be at least 4 inches of concrete above the highest point of plate. Buckled plates

88. In decked bridges, and footwalks outside trusses, an iron or steel railing of approved design not less than 4 feet high, shall be placed on the outer line of sidewalks. Railings

The railings shall rest directly on the floor-beams and be securely braced laterally, with adequate outside stays riveted thereto, if directed by the Engineer.

In through bridges the openings in the trusses must be filled with a steel, or iron, railing of suitable design.

The top flange of railings shall be proportioned to withstand a transverse horizontal thrust of not less than 45 pounds per lineal foot.

Railings shall extend over piers and abutments, and terminate in an ornamental post, or as directed by the Engineer.

The tees and angles of railings shall be straight and out of wind. The joints shall be planed and make close contact without any projection of one length above another. The filling between the rails of lattice bars or angles shall be in a vertical plane, and not more than 9 inches between lattice. Buckled lattice will be rejected.

Bridge works, when unable to construct a satisfactory railing, will be required to have it constructed by shops familiar with this character of work.

89. No material in highway bridges, erected by the Department of Railways and Canals, shall be less in thickness than 5/16 inch. Channels less than 6 inches will not be used, except in laterals. Angles less than 2½ × 2½ × 5/16-inch section will not be used. Minimum sections

In swing bridges, the top flange and web of drum shall not be less than ⅝-inch thick and the bottom flange ½-inch thick.

90. Chords shall be of box section. T chords will not be permitted by the Department of Railways and Canals. No T chords.

91. The material and character of the work, erected by the Department of Railways and Canals, shall be the same as required for railway structures as subsequently stipulated. Material and workmanship.

STRUCTURAL LOADS.

92. The live load shall be of two classes, or such other load as may be specified by the Engineer. Live loads.

Class I.—A load on each square foot of floor and sidewalk of 100 pounds for all spans up to 100 feet and 80 pounds for spans 250 feet and over, and reduced uniformly for spans between 100 feet and 250 feet.

A concentrated load of 40,000 pounds equally distributed upon axles 10 feet apart, or 24,000 pounds on axles 8 feet apart whichever is specified by the Engineer.

Class II.—A load, on each square foot of floor and sidewalk, of 80 pounds for spans up to 100 feet, of 50 pounds for spans of 250 feet, and reduced uniformly for spans between 100 and 250 feet.

A concentrated load of 16,000 pounds, equally distributed upon two pairs of wheels, 6 feet apart, on axles 8 feet apart, or a road roller clause 94.

No span shall be proportioned for a live load less than 1,200 pounds per lineal foot.

Dead loads.

93. The dead load shall be the weight of the metal in the structure, and the weight of floor or paving. The weight of timber will be estimated at 4 pounds per foot B.M.

Road roller.

94. The floor system of highway bridges will be proportioned for a steam road roller, the loads being distributed as shown upon Diagram B. The stresses produced by the roller will be decreased 50 per cent in proportioning such members as may be affected.

The stresses produced by the road roller will be assumed to be equally divided between the joists it covers. The wheel concentrated loads from Classes I and II will be divided equally between two joists.

Calculation maximum stresses.

95. In proportioning the various members of the structure all positions of the above live loads, together with the dead load, shall be taken and the maximum stresses calculated thereon.

Wind bracing.

96. Wind bracing shall be proportioned to resist a lateral force of 300 pounds, considered as a moving load, for each foot of span on the top lateral bracing of deck bridges and the bottom lateral bracing of through bridges.

The bottom lateral bracing in deck bridges and the top lateral bracing in through bridges shall be proportioned to resist a lateral force of 150 pounds, considered as a moving load, for each foot of span.

Bridges of over 200 feet span will have the lateral and wind bracing, designed according to the exposed surface area. Clause 120.

Unit stress.

97. The unit stresses and limiting lengths for highway bridges shall be determined by increasing the stresses, hereafter specified, for railway structures 25 per cent.

Loads on car tracks.

98. Highway bridges, which carry electric cars, shall have the above specified loads increased to provide for the loads upon the car tracks.

ELECTRIC RAILWAY BRIDGES.

99. In through bridges there shall be a clear width of at least 6½ feet on each side of the centre of track, at a height of 12 inches above the rail. Clearance.

Upon a curved track the clearance shall be correspondingly greater calculated with a car 42 feet in length, 8 feet in width and 30 feet between centres of trucks. The edge of the running board shall have at least 9 inches clearance of any part of truss and at least 6 inches above it. Through bridges shall have a clear head room, above the top of rail, of at least 15 feet, for a width of 6 feet over the railway track.

100. The floor system will be constructed of timber similar in character and in the manner hereinafter provided for steam railways. Floor system.

101. The cross ties shall be at least 5 inches by 7 inches and not less than 10 feet in length and spaced not over 6 inches in the clear. Cross ties.

102. The ties shall be boxed not less than ½-inch upon steel stringers and every fourth tie shall be secured thereto by ⅝-inch hook bolts.

103. Ties resting upon plate girders, or trusses, with cover-plates shall be grooved for the rivets and boxed to the depth of the plate. Ties resting upon wooden stringers every third tie shall be securely spiked or bolted to the stringers.

104. Near the end of the ties there shall extend on each side a timber not less than 6 inches by 6 inches, notched 1 inch over the ties and bolted to every third tie by a ⅝-inch bolt. Guard timbers.

105. Preferably there will be inside steel guard rails which will extend such distance beyond the abutments as the Engineer may direct and come to a point in the centre of the track, the point being protected by a frog point. The rails will be 8 inches in the clear of the inside of track rail and will be spiked to every tie. Steel guard rails.

STRUCTURAL LOADS.

106. For calculation of wind stresses, the exposed surface of the loaded structure shall be that of the unloaded structure and an exposed surface of 10 feet in height and 40 feet long, the pressure on which will be considered a moving load. Lateral force, exposed surface area, clause 130. Wind stresses.

107. Centrifugal force will be assumed at 10 pounds per running foot for each degree of curvature acting at 5 feet above the base of rail. Centrifugal force.

108. A longitudinal force, due to traction and the application of the brakes, shall be provided for, equal to 15,000 pounds applied at the top of rail. Longitudinal force.

109. The structure shall be proportioned for the subsequently specified dead and live loads. Loads.

Dead loads. 110. The dead load shall be the weight of the entire structure, including the floor system, rails and guard rails. The weight of timber being assumed at 4 pounds per foot, board measure. The weight of rails, steel guard rails, spikes and bolts, shall be estimated at not less than 100 pounds per lineal foot of each track, and the total weight of floor above the stringers shall not be taken at less than 300 pounds per running foot of each track. Structures to carry steam railway freight cars, the dead load will be proportioned accordingly.

Live loads. 111. The live load for electric railways will be as denoted on diagram 'B,' or as specified by the Engineer. When carrying heavy freight the loading will generally be—Class Special Light. Diagram B, page 52.

Unit stresses 112. The unit stresses for electric railway bridges shall be determined by increasing the stresses, hereinafter specified for steam railway structures, 12½ per cent.

RAILWAY BRIDGES.

Cross ties. 113. Cross ties and guard timbers shall be southern long-leaved pine, white or red pine or Douglas fir of British Columbia.

The ties, for deck truss spans without stringers, shall be at least 8 inches by 12 inches, or of such a depth that the weight of a pair of locomotive driving wheels, distributed over three ties, will not give a fibre stress greater than specified hereafter for the kind of timber made use of, the ties will be spaced 4 inches apart, and shall be 14 feet in length.

The ties, for through truss girders, shall be not less than 8 inches by 8 inches, when there are four lines of stringers; when there are two lines they shall be not less than 8 inches by 10 inches; in both cases there shall not exceed a fibre stress, determined as above according to the wheel loads specified; they shall be spaced 12 inches centre to centre, their length shall be 14 feet, and at least every fourth tie shall extend the width of the bridge to carry a plank side walk on each side.

On curves the outer rail will be elevated ½-inch per degree, and this elevation will be framed in the ties as no shims will be allowed.

Ties shall be boxed, to a close fit, not less than ½-inch nor more than 1½ inches on to the stringers, and every fourth tie shall be secured thereto by ¾-inch hook bolts flattened at their lower ends which will pass through the guard rails when practicable.

Guard rails. 114. There shall be four lines of guard rails; the 'outer lines' of timber will be placed 5 feet 5 inches clear from the centre of the track and shall be 9 inches wide by 8 inches deep, notched, not less than 1 inch, on to the ties and secured to every fourth tie by ¾-inch bolts with washers; 'the inner lines,' when of timber, will be placed 3 feet 3 inches clear from the centre of track; they will be 8 inches wide by 5 inches deep, notched 1 inch on to the ties.

The projection between the notches of both lines will be secured by four nails driven previous to the notches being cut.

The inner guard rails will be secured to every fourth tie by ¾-inch bolts, and to all intermediate ties by spikes ⅝-inch square by 8 inches long; they will curve into the outer guard rails, in rear of abutments, and be secured to them by ¾-inch bolts.

The upper angle next the rails will be protected with angle iron, 3 inches by 3 inches by ⅜-inch, fastened to the timber with counter-sunk spikes ⅝-inch diameter, or by ⅝-inch woodscrews 4 inches long, and spaced 6 inches at ends and 18 inches at intermediates. The holes in angle irons must be slotted to allow for contraction and expansion; the heads of the bolts shall not be higher than the angle irons.

The guard rails will be spliced over the ties with a half and half joint with 6 inches lap. Each splice shall have a ¾-inch bolt at centre; holes to be bored ⅛-inch larger to allow for expansion.

If directed and specified, steel rails or heavy angle irons will be substituted for the inner lines of guard rails.

The guard timbers shall extend over all piers, and 15 feet over abutments.

115. Preferable limiting lengths for different types of railway bridges:— Preferable lengths.

Spans under 18 feet..	Rolled beams.
Spans between 18 feet and 100 feet....	Riveted plate girders.
Spans between 100 feet and 200 feet..	Riveted triangular trusses.
Spans from 200 upwards..	Pin connected single intersection or riveted trusses.

116. From centre to centre of through trusses the width shall be not less than one-twentieth of the effective span. Widths.

From centre to centre of decked pin-connected, or riveted trusses, the width shall be not less than 10 feet nor one-fifteenth of span.

117. The clear open section shall be, on a straight track, not less than shown on appended diagram 'A.' (page 51). Clearance.

On a curved track the clear width must be increased to provide the same minimum clearance between cars and trusses for a car 80 feet long and 59 feet between the centres of trucks, allowance having been made for curvature and superelevation of rails.

Double tracks will be generally placed 13 feet centre to centre.

The headway clearance must in all cases comply with the statute, 3 Edward VII., Ch. 58, section 202, which requires that every bridge or structure, through which a railway passes, shall have an open, or clear, headway of at least 7 feet between the top of the highest freight car, used on the railway, and the bottom of the lower beams, members, or portions, of that part of such bridge, or structure, over the railway.

STRUCTURAL LOADS.

Dead loads steam railways. In proportioning the members of structures they shall be proportioned for the following dead and live loads.

118. The dead load shall be the weight of the entire structure, including the floor system, rails, &c., and guard timbers.

The weight of the ties, guard timbers, rails, &c., shall be assumed at 650 pounds per lineal foot for 8 inches by 10 inches ties and 14 feet in length. For larger ties the additional weight of timber will be calculated at 4 pounds per foot, board measure.

Two-thirds of the dead load shall be assumed to be concentrated at the joints of the lower chord in through bridges and the upper chord in decked bridges, and one-third of the dead load at the joints of the upper chord of through and the lower chord of decked bridges.

Live loads. 119. A live load, on each track, as may be designated from the appended diagram 'B' (page 52), consisting of two consolidated locomotives coupled, connected with and followed by a train of a stated weight per lineal foot, but in no case shall the live load be less than one of the classes, nor less than the two heaviest consolidated locomotives running upon the railroad.

If, in case, a live load of 100,000 pounds for Class II and under, and 120,000 pounds above Class II, on two axles spaced 7 feet apart, would produce greater stresses than those due to the live load, as above, such load shall be provided for.

Diagram 'B' is based upon the weight of locomotives now in operation; the minimum live load suggested is Class II, with other classes proportional. (Table I.) Note clause 140 which produces a heavier floor system.

The force of wind shall be considered a moving load and without impact increment.

Lateral bracing and wind force. 120. The bottom lateral bracing, in decked bridges and the top lateral bracing in through bridges, shall be proportioned to resist a uniformly distributed lateral force of 200 pounds per lineal foot of bridge for all spans 200 feet and under.

The bottom lateral bracing, in through bridges and the top lateral bracing in decked bridges of 200 feet span and under, shall be proportioned to resist a force of 600 pounds per lineal foot, applied at a height 8 feet above the base of rail.

Bridges of more than 200 feet span shall have the wind bracing designed for the exposed surface area.

First,—the full live load on structure; the wind pressure will be assumed at 30 pounds per square foot on the exposed area of surface of all trusses and of the floor taken in elevation, and on the exposed area of a train, of 10 feet in average height commencing 2 feet 6 inches above base of rail, moving across the bridge.

Second,—the wind pressure will be assumed at 50 pounds per square foot on the exposed area of surface with no live load on structure.

In proportioning lateral bracing, take the result of the two conditions which will give the greatest area of section, but in either case not less than that found for spans under 200 feet.

121. Centrifugal force, for structures upon a curve, shall be assumed to act 6 feet above the base of rail, and be taken at 0·03 of the live load for each degree of curvature up to five degrees; this co-efficient (0·03) will be reduced 0·001 for every degree of curvature above five degrees.

Centrifugal force.

122. Longitudinal force, to be applied on the rail, shall be taken at 20 per cent of the maximum moving load on the structure.

Longitudinal force.

123. Variations in length from a change of temperature of 150° Fahr. shall be provided for.

Temperature variations.

STRESSES.

124. All parts of the structure shall be proportioned to sustain the maximum stresses produced by the live and dead loads specified and of the wind and centrifugal force.

Maximum stresses.

125. For calculating stresses, the length of spans will be the distance between centres of end pins of pin-connected trusses, and the distance between the centres of bearing plates of other girders.

Dimensions for calculating stresses.

The length of stringers will be the distance between centres of floor beams and the length of floor beams the distance between centres of trusses.

The depth, for calculation of girders, will be the distance between centres of gravity of flange section, provided it does not exceed the distance out to out of angles, in which case the latter will be considered the depth.

The length of posts and compression diagonals in pin bridges shall be the centre to centre distance of pins. In rivetted spans the length may be taken between connection plates, except in trestle posts, when the length will be from cap or base plate to the centre of intermediate struts.

The bending in rivets and pins will be estimated at the distance between centres of bearing.

126. Centrifugal force stresses shall be calculated as a part of the live load.

Centrifugal force stresses.

127. Longitudinal force stresses shall be taken separately (without impact) at the specified unit stresses, or in conjunction with the dead

Longitudinal force stresses.

load, live load, and impact or dead load, live load, impact, and wind at the specified unit stresses plus 25 per cent.

Stresses from uniform load.

128. In the calculation of stresses from a moving uniform load, the load shall cover the panel in advance of the point considered ; but the half panel load going to the forward panel will not be considered.

Net section tension.

129. The net section of any tension flange, or member, shall be determined by a plane cutting the member square across at any point. The greatest number of rivet holes which can be cut by the plane, or come closer than 2 inches of the plane, are to be deducted from the gross area of section.

Lateral diagonals.

130. When lateral diagonals are incapable of taking one-half the shear of any panel, considered in compression, they shall be proportioned for tension solely.

Combined stresses.

131. The stresses from the assumed wind forces, or in combination with any centrifugal or temperature stress, need not be considered, unless the wind stresses on any member exceed one-quarter of the maximum stresses due to the live and dead load upon the same member, the section will then be increased until the total stress per square inch will not exceed by more than one-quarter the maximum fixed for live and dead load.

Wind force when to be considered.

132. When the wind stress, as above, or in combination with a possible temperature stress, can neutralize or reverse the tension in any part of the lower chord, it shall be stiffened.

Stiffened chords will be proportioned to take compression arising from the specified wind loads and tractive stresses.

Initial stress laterals.

133. In excess of wind stress, lateral and longitudinal struts will be proportioned to resist the resultant of an initial stress of 10,000 pounds per square inch upon all rods connected to them.

Assumed load for anchorage.

134. To obtain the anchorage required for a loaded structure the train will be assumed at 800 pounds per lineal foot.

Collision struts.

135. Collision struts, placed in the best position to take the shock of a derailed train striking 4 feet 6 inches above the base of rail, will be proportioned to take a thrust of 50,000 pounds acting in the direction of the plane of truss.

Combined direct and bending stresses.

136. A member subject to bending and traverse stress, as when the ties rest upon the chords of bridges, in addition to the direct stress due to its position it shall be considered as a beam of one panel length supported at the ends. The member will be proportioned to sustain the algebraic sum of the stresses resulting from the direct stress and three-fourths of the stresses resulting from the maximum bending moment. Impact will be added to both loadings. The bending moment at the panel points will be considered equal to that at the centre, but in opposite direction.

IMPACT.

Impact.

137. To counteract the effect of impact and vibrations, the stresses, produced by the specified dead and live loads, shall be increased by the following formulae.

Stresses in one direction.

138. In each member, stressed in one direction, either tension or compression, the stresses, resultant from the dead and live load, shall be increased by the quotient of, the square of the live load stress divided by the sum of the dead and live load stresses.

Stresses in opposite directions.

139. In each member stressed in an opposite direction, or alternate live load stresses of tension and compression, the impact will be computed by the preceding clause (138) considering the dead and live load stresses of the same sign increased by eight-tenths of the algebraic sum of the dead load stress and double the live load stress in the opposite direction or sign.

The impact will be considered either as tension or compression and shall be added to the algebraic sum of the dead load stress and the live load tension or the dead load stress and the live load compression. Members will be designed for both stresses.

Impact, spans under 80 feet.

140. In spans under 80 feet the live load shall be multiplied by the factor $\left(1.40 - \frac{L}{200}\right)$ in which L = length of loaded distance in feet which produces the maximum stress.

This formula applies to any member of a truss which receives its maximum stress from a loading extending over a distance of less than 80 feet.

Counters.

141. In such members which have dead and live loads of an opposite character; only 70 per cent of the dead load stress shall be considered as effective.

UNIT STRESSES.

ON MEDIUM STEEL.

Compression stress formulae.

142. The unit stresses for compression members having a greater ratio of length by the radius of gyration than thirty-five are to be reduced by the following formulae where l=the length of the compression member in inches and r the least radius of gyration in inches.

I. For flat or fixed ends :—

$$\text{Permissible stress} \div 1 + \left(\frac{l^2}{18000\, r^2}\right)$$

II. One flat and one pin end :—

$$\text{Permissible stress} \div 1 + \left(\frac{l^2}{12000\, r^2}\right)$$

III. Pin at both ends :—

$$\text{Permissible stress} \div 1 + \left(\frac{l^2}{9000\, r^2}\right)$$

Formula III. Shall be used for all trestle posts.

Unsupported lengths.

143. No compression member shall have a length exceeding forty-five times its least width, nor an unsupported length in any direction exceeding 100 times its least radius of gyration, about an axis perpendicular to that direction, excepting wind bracing and lateral struts, which may have an unsupported length of 120 times the least radius of gyration.

Permissible stresses.

144. The maximum stresses in any part of a structure shall not exceed the following amounts in pounds per square inch, except the unit tensile stress for eye-bars, which will be 17,000 pounds per square inch.

PERMISSIBLE UNIT STRESS ON MEDIUM STEEL, 16,000.

SHEARING.

145. On shop driven rivets in reamed or drilled holes. .11,000

On pins.. 12,500

On webs of girders, gross area.. 10,000

BENDING.

146. Bending on outer fibres of pins.. 25,000

Bending, on extreme fibres of rolled shapes, built sections and girders ; net sections.. 16,000

BEARING.

147. On diameter of shop driven rivets in reamed or drilled holes.. 22,000

Pins.. 25,000

Field rivets and bolts.

148. Field rivets shall be increased 25 per cent above the number determined by the above stresses if driven by hand and 10 per cent if driven by power. Turned bolts will be taken at the unit stress of field rivets.

Roller stress.

149. Per lineal inch of rollers or rockers, cast-iron... 750 √ D.

Per lineal inch of rollers or rockers, steel.... 1,200 √ D.

'D' represents the diameter of the roller in inches.

Bearing of discs.

150. Steel and bronze discs of pivots of swing bridges. 3,000

Bearing of bed plates.

151. Bed-plates, &c., upon first-class masonry ; and upon Portland cement concrete, not less than one month old :

Sandstone..	300	pounds	per square inch.
Concrete..........................	400	"	"
Sound limestone	400	"	"
Granite	600	"	"

152. TIMBER.

	Tension.	Compression.			Extreme fibre stress.	Shearing.	
	With grain.	End bearings.	Columns under 15 diameters.	Across grain.		With grain.	Across grain.
White Oak	1,000	[illegible]	[illegible]	500	1,000	[illegible]	[illegible]
Georgia Long Leaf Yellow Pine	[illegible]	[illegible]	[illegible]	350	[illegible]	[illegible]	[illegible]
Douglas, Oregon and Yellow Fir	[illegible]	[illegible]	[illegible]	310	[illegible]	[illegible]	[illegible]
Canadian White and Red Pine	1,100	[illegible]	[illegible]	170	[illegible]	[illegible]	[illegible]
Spruce and Eastern Fir	1,100	[illegible]	[illegible]	170	[illegible]	[illegible]	[illegible]
Hemlock	1,000	[illegible]	[illegible]	150	[illegible]	[illegible]	[illegible]

153. Columns and struts, with flat ends, over 15 diameters. Timber columns.

l = length of pillar in inches. d = diameter in inches.

Southern Yellow Pine and Douglas Fir.	White Oak.	White Pine and Spruce.
1200	1000	800
$1+\frac{l^2}{1000\,d^2}$	$1+\frac{l^2}{1000\,d^2}$	$1+\frac{l^2}{1000\,d^2}$

154. The permissible stresses for timber are static when combined with a live load use impact formula and increase the above stresses by 50 per cent. Impact to be added to timber stresses.

UNIT STRESSES FOR ELECTRIC RAILWAY AND HIGHWAY BRIDGES.

155. Twelve and one and one-half per cent in excess of the preceding unit stresses and limiting lengths for bridges carrying electric railways.

Twenty-five per cent in excess of the preceding unit stresses and limiting lengths for highway bridges.

CO-EFFICIENT OF FRICTION.

156. Wrought iron or steel on itself..	·15
Wrought iron or steel on cast-iron..	·20
Wrought iron or steel on masonry..	·25
Wheels on rails..	·20
Masonry on itself..	·50

PLATE GIRDERS.

FLOOR BEAMS AND STRINGERS.

Decked plate girders. 157. Decked plate girders, when directed, will have the top flange made up of four angles and side plates; they shall have brace frames at the ends, and intermediate frames, spaced not more than 15 feet apart, consisting of plates, and at least four angles, top, bottom, and two diagonal angles.

End brace frames. 158. The end brace frames shall be proportioned to resist all the stresses that accumulate at the ends.

Skew bridges. 159. The ends of decked plate girders of skew bridges shall be square to the track at the abutments.

Lateral bracing. 160. Lateral bracing will extend from end to end, and no brace will make an angle less than 30 degrees with the girders, excepting end braces of skews spans.

Rivet spacing. 161. Rivet spacing in the top flanges of decked girders will not exceed 4 inches pitch.

Width. 162. Width of decked plate girders shall not be less than 8 feet from centre to centre of girders.

Through plate girders. 163. In through plate girder spans, the track shall be carried on steel floor beams, spaced not exceeding 15 feet apart, and stringers.

Sway bracing. 164. The sway bracing shall be a triangular gusset plate running from the top flange of the girder to each floor beam, or transverse strut, and at the ends.

For through plate girders with solid floors the distance between knee braces or gusset plates shall not exceed 12 feet.

Girders with shelf angles. 165. In spans where the base of rail is sufficiently near the top flange so that the clearance will allow the girder to be spaced not over 14 feet, centre to centre, the cross ties may, when permitted, be supported upon shelf angles riveted to the web.

Shelf angles shall not be less than 5 inches by 3½ inches by ⅝-inch riveted to webs by ⅞-inch diameter rivets pitched not more than 4 inches centre to centre.

There shall be distributing angles 3 inches by 4 inches, resting on bottom flange angles and riveted to the web under the shelf angles about 3 feet apart.

Sway bracing. 166. The top flanges of the girders shall be stayed laterally by gusset plates extending the full depth of girder and connected by cross struts of solid web and angles as deep as possible, and in any case shall not be less than 15 inches deep and spaced not over 12 feet apart.

167. Clearance of through plate girders, diagram 'A,' page 51. Clearance.

168. The depth of plate girders will be preferably 1/8 to 1/12 of span when practicable. Depth.

Plate girders shall be built with as few splices in web as the longest plate procurable will permit. Long pieces.

STIFFENERS.

169. When the unsupported distance between the flange angles exceeds fifty times the thickness of the web vertical stiffeners of angles shall be placed on each side of web.

170. The stiffeners, in girders over 4 feet in depth, are to be placed a distance apart, centre to centre, not exceeding the depth of the full web plate. Spacing of stiffeners.

In girders under 4 feet in depth they may be 4 feet apart.

If unequally spaced the distance between them will gradually decrease towards the ends.

Stiffeners will be placed at all points of concentrated loading.

171. Over the end bearings, at each end of bed plates, there shall be two pair of stiffeners upon fillers, the projecting legs of which shall be as wide as the flange angles will permit. These stiffeners, including fillers, shall be proportioned to resist the maximum shear as a column considered one-half the depth of the girder in length. The rivet connection of the web shall be proportioned at unit stresses to transfer the total shear to the column. Stiffeners over end bearing.

172. Fillers under stiffeners shall be the same thickness as flange angles and as wide as stiffeners. Fillers.

173. Intermediate stiffeners may be on fillers or crimped over the flange angles, except in floor beams or stringers connected to them there shall be fillers. Intermediate stringers.

174. Intermediate stiffeners shall be of the following dimensions :— Dimensions of stiffeners.

For webs 3 feet and under	3" x 2½ x ⅜" angles.
" 4 feet..	3" x 3" x ⅜" "
" 5 feet..	3½"x 3½ x ⅜" "
" 6 feet..	3" x 4" x ⅜" "
" 7 feet..	3½"x 5" x ⅜" "

175. Ends of stiffeners shall be made to come to as close a fit under flanges as possible without buckling flanges. Close fit.

176. The rivet pitch of stiffeners shall not exceed 5 inches. Rivet pitch.

Splice and flange plates. 177. The width of splice plates shall be sufficient to admit the requisite number of rivets and to receive the stiffeners. They will develop the full strength of the nett section of the web. The main splice plates, not less than ⅜-inch thick will extend from flange to flange and will have at least two rows of rivets on each side of the joints. In addition two splice plates will cover the vertical legs of the flange angles.

Cover plate. 178. Girders having flange plates will have the plate, next to angles on top flange, extend from end to end.

Compression flange. 179. The compression flange of plate girders shall have the same cross section as the tension flange, and the width of the flange shall not be less than one-twelfth of the distance between its side supports.

It is preferable that, as far as practicable, over half the flange section will be of angles. Heavy sections of angles will be used with as few cover plates as possible.

Flange plate. 180. Flange plates shall be of such lengths as will permit of at least two rows of rivets, of the regular pitch, being placed at each end of the plate beyond the theoretical point required.

Flange angle. 181. Flange angles must be spliced with angle covers and plates whenever cut within the length of girder.

Cover plates. 182. When two or more cover plates are used they will be of equal thickness or decrease in thickness outwards, when they project more than 3 inches beyond the edge of flange angles, an extra line of rivets shall be driven along each edge, 9 inches pitch for the outer row.

Joints in flanges. 183. All joints in flanges, whether in tension or compression, must be fully spliced and covered by an amount of extra material equal in section to the pieces spliced, and with sufficient rivets on either side to transmit the stresses from the parts cut.

The ends of joints must be dressed straight and true ; there shall be no open joints.

Web plates. 184. Web plates in railway bridges shall not be less than ⅜-inch thick and must be arranged so as not to project beyond the face of flange nor on the top to be more than 1/16-inch below the face of angles at any point.

Flange rivets. 185. No rivet hole shall be pitched nearer than 1¼ inches to a roll finished or machine edge of web.

The minimum pitch of rivets shall be three times their diameter from centre to centre.

Shear and bearing on rivets. When calculating the shearing and bearing stresses on rivets connecting the web to the flanges, the total shear acting on the outside of any section at any point is to be considered as transferred to the flange angles in a distance equal to the depth of girder at that point and in addition any load applied directly on the flange, the wheel loads, when the ties rest on the flanges, shall be assumed to be distributed over three ties.

Stays

186. The compression flanges of girders shall be stayed at intervals not exceeding fifteen times their width.

Proportioning plate girders.

187. Girders shall be proportioned so that the bending or chord stresses are resisted by the upper and lower flanges, and that shearing or web stresses are resisted by the web plate.

Web to be estimated as flange area.

188. One-eighth of the area of web plate may be estimated as flange area; at web splices the full area of section will be required, either by extending the flange plates, or by extra splice plates.

End finish

189. Through plate girders will be finished at the ends. They will have a plate of the width of cover plate riveted to the end stiffeners and a corner cover at the top riveted to top and end plates, or they will have the upper corners rounded off, as may be directed and specified by the Engineer.

Sliding and roller bearings

190. Girders must be provided with planed sliding bearings, allowing for the variation of temperature, and so arranged as to prevent lateral motion. Slotted holes will be provided for the anchor bolts at one end of the span.

Girders 80 feet and over in span must be provided with rollers at one end, which shall not be less than 5 inches in diameter.

Bed plates

191. Bed plates shall be of adequate thickness, not less than ¾-inch thick, to insure uniform pressure over the masonry, which shall not exceed that specified. They shall project at least 1 inch beyond the second pair of stiffeners.

The bed plates and bearings under fixed and roller ends must be fixed bolted to the masonry with bolts not less than 1¼-inch diameter.

Cross ties angles

192. Cross ties, resting on shelf angles in low through plate girders, shall be at least 8 inches by 15 inches deep, spaced 12 inches centre to centre, or of such a depth, that the weight of the locomotive driving wheels specified distributed over three ties, will not exceed the fibre stress specified.

STRINGERS AND FLOOR BEAMS.

Distance apart of stringers

193. Stringers will be placed, in general, 8 feet between centres. Where there are four lines of stringers, the outside lines will be proportioned to sustain one-half the load on the interior main stringers. In double track bridges the stringers will be 6½ feet apart.

The track stringers of skew bridges at the abutments shall be square to the track.

End angles and rivets. 194. The end angles of stringers shall not be less than ⅜-inch thick; the connecting rivets to the web shall be proportioned to resist the bending introduced by their distance from the centre line of floor beam in addition to the direct shearing stress. Shelf angles or other supports provided to support the stringer during erection shall not be considered as carrying any of the reaction.

Holes reamed to template. 195. All the holes for field rivets in stringers and floor beam connections will be punched 1/16-inch smaller than the finished diameter and reamed to an iron template.

Lateral bracing. 196. Stringers shall be braced laterally when their unsupported length exceeds eighteen times the width of flange. The bracing will consist of diagonal angles at the top flange and brace frames will be used in panels of 30 feet or over.

At the intersection of the lower truss lateral diagonals transverse angles will, preferably, be placed between the stringers.

Rivet pitch. 197. The rivet pitch through the web in top flanges of stringers will not exceed 4 inches.

Floor beams when riveted to posts. 198. Floor beams in bridges with pin connected chord, shall be riveted to the posts above or below the pins of the bottom chord in through bridges, and in decked bridges preferably, below the top chord; they shall, preferably, be square to the trusses or girders.

End floor beams. 199. All spans will have, preferably, end floor beams to support stringers.

Web plates and flange angles. 200. Web plates of floor beams and stringers shall not be less than ⅜-inch thick, and with the flange angles will run the full length without splices.

Stringers on top of floor beams. 201. Stringers, when resting on top of floor beams, will be riveted to the floor beam, and knee braces shall support both ends of each line of stringers. On the masonry they will have cross struts and be stayed to the main shoes of the girders or trusses.

Hangers for floor beams. 202. If hangers are permitted they will be either solid forged eye-bars riveted to floor beams, or riveted plate hangers. Stirrup hangers or bent hangers will not be allowed.

Eye-bar hangers will have sufficient excess of material across the eye, all rivet holes in them will be bored and the edges of the holes chamfered for a filler under rivet head. All riveted hangers will have excess sections at the pin holes.

I-BEAM SPANS.

Beams. 203. In I-beam spans the beams will preferably be double under each rail; they will have planed sole plates riveted to the flanges, and bolted through the bed plates to the masonry at one end, and free to slide longitudinally at the other; they will have rigid cross struts and transverse bracing riveted to the webs. There will be stiffening angles at both ends with close fit to flanges; when in pairs they will have wrought metal separators. Beams shall be proportioned by their moment of inertia. The width of flanges shall not be less than one-sixteenth of the distance between supports.

TRESTLES.

Construction of towers.

204. The tower and open spans of trestles will be made of such length that the depth of the girders will be, preferably, similar and avoid objectional details in connecting the spans to the columns.

The towers shall be constructed of two columns, not less than 8 feet apart at top, braced transversely, top and bottom forming a bent, and two bents braced longitudinally will constitute the tower. There shall be no adjustable members, all of which shall be riveted.

The foot of each post and intermediate joint of a tower shall be braced longitudinally and transversely by struts at top and bottom, and the diagonals shall be stiff members.

Longitudinal bracing.

205. The towers shall be braced longitudinally so that they shall resist at limiting unit stresses, the tractive force of the engine or the momentum caused by suddenly stopping upon any part of trestle the maximum train load.

Horizontal struts.

The horizontal struts at the foot of towers shall be of sufficient strength in compression to slide the movable shoes when the track is unloaded.

Expansion joints and cross frames.

206. Girders, connecting bents, shall be riveted to the tops of columns at each end and free girders shall be provided with an expansion joint at one end. They shall be secured against displacement sideways by substantial guides.

Cross frames shall be used at each end of each pair of girders, and shall not be common to two adjacent spans.

Batter.

207. When practicable the trestle bent shall have a 'batter,' or spread of base in order that no tension will result in the windward trestle leg from the wind and centrifugal force combined with the vertical forces, but when not practicable sufficiently large and long bolts and washers shall be provided to anchor the legs to the masonry, provision being made for expansion and contraction.

Wind bracing.

208. The bracing and posts of towers shall be proportioned for a force of 300 pounds per lineal foot of structure applied 8 feet above the base of rail; also a force of 30 pounds per square foot of the area of structure loaded, and 50 pounds per square foot of the structure not loaded, against the girders and floor; a force upon the bents of 225

pounds per foot of height, structure loaded, and 375 pounds per foot of height structure unloaded.

Length for stresses.

209. The length assumed for calculating stresses in posts shall be from cap or bed plates to the centre of intermediate struts.

DRAWBRIDGES.

Turntable and drum.

210. The turntable shall be of a type subject to the approval of the Engineer, and proportioned as specified for plate girders. Preferably the load of the trusses will be transmitted to the turntable at eight or more points of loading.

Bottom flange planed.

211. The bottom flange shall have sufficient excess of metal to allow for planing and no material less than [illegible]-inch thick will be used in the drum.

The drum shall be perfectly round and planed to a true surface on its under side to receive the wheel treads.

Stiffener angles.

212. The drum shall be stiffened by stiffener angles at all points of concentrated loading.

Thickness of web plate.

213. The web plate shall be of such thickness that the rivets, supporting the lower flange angles, shall have sufficient bearing to distribute the load from one wheel to the web plate, in a distance equal to three-fourths of its diameter.

Treads.

214. The upper treads will be made of steel, planed and finished all over to the exact dimensions, so as to fit closely drum, rollers, and at joints of segment. They shall be riveted to the circular girder by [illegible]-inch rivets, countersunk, with not more than 8-inch pitch.

The lower tread segment face and ends will be planed and fastened to pivot pier by bolts not less than 1-inch diameter and 15 inches long.

Rollers.

215. The rollers will be of cast-iron chilled, when specified, or of cast steel, preferably steel. The rollers and the surfaces of the upper and lower treads shall be turned to form parts of conical surfaces with a common vertex at the centre of turntable.

Centre pin.

216. When a proportion of the load or the entire load is supported upon a centre pin there will be three discs, the upper and lower of hard steel, the middle disc of phosphor bronze.

Centre casting.

217. The centre casting must possess excess of strength and be secured to masonry by bolts not less than 2 feet long and if desired it will be let into the masonry.

Brackets.

218. The brackets supporting the pinions which gear in the rack shall be built of sections of rolled steel.

Oil holes.

219. Oil holes and grooves will be provided for all bearings, which must be entirely free from dirt when covered and have holes provided.

Rack segments.

220. The rack segments shall be cast in short lengths, the ends planed and the bearing of both rack and lower tread will be planed.

Racks and gears.

221. Cast racks and gears shall have the pitch lines of teeth exactly in the same plane. Gears shall be true to bevel, truly circular and bored at right angles to the plane of action to accurately fit shafts. The teeth in racks and gears will be machine-cut, when specified, to exact pitch, and shall in all cases mesh accurately. Gear and rack teeth will be proportioned according to Table 7, page 61. The hubs of gears will be faced.

Gears and shafting.

222. Gear wheels will be of cast steel with machine-cut teeth when specified. Pinions with cast teeth shall be shrouded on top.

The shafting will be of cold rolled steel with sufficient coupling collars and keys; no shaft will be less than 2½ inches in diameter.

End lifts.

223. Effective end lifts of an improved design shall be provided. The lifts shall give the necessary reaction in the shortest possible time and prevent the ends of bridge being raised by a load on the opposite arm.

Latches.

224. There shall be strong latches at each end of span which will close automatically and be easily released. Latch catches will be provided to secure the bridge when open.

Turning machinery.

225. The power machinery for turning the bridge shall be arranged for turning it completely around in either direction. Two rack pinions shall be provided, unless otherwise specified.

Hand power machinery, with two speeds, is to be provided in all cases when other power is used.

Rail lifts.

226. Suitable rail lifts, in connection with the end lifts, and guide chairs shall be provided.

Turntable to be assembled in shop.

227. The treads, wheels and drums shall be completely assembled in the shop before shipment, all holes perfectly reamed and the sections match-marked. Every wheel must have a true bearing on the tread; wheels and tread shall be entirely machine-finished, and the under side of surfaces bearing on the masonry shall be planed.

Machinery design and finish.

228. In designing the machinery it must be considered that all parts shall be accessible for inspection and removal. All machinery must be finished in accordance with the best machine-shop practice and fitted up with the greatest care.

Provision for draining.

229. Provision will be made, by channels and weep holes underneath lower tread and rack, to drain the top of pier.

All spaces in castings will be filled with fine concrete or other waterproof material.

Conditions for calculating stresses.

230. In ascertaining the stresses in the trusses of swing bridges, the following conditions will be considered :—

Case I. Maximum stresses, dead load only acting, bridge swinging or open.

Case II. Maximum stresses, dead load only acting, bridge closed, ends raised, continuous girder over three supports.

Case III. Maximum stresses from live load, bridge considered as continuous over three supports, live load coming on at one end and advancing panel by panel until bridge is covered.

Case IV. Maximum stresses from the live load, bridge considered as continuous, live load on one arm, only, advancing from centre pier to abutment.

Case V. Maximum stresses from live load one arm considered as a single span, live load advancing from either end.

Maximum stresses.

231. Maximum stresses shall be determined by combining Case I or II with Case III and IV, or Case I with Case V, with impact in each case.

When considering Case I alone, the stresses from the dead load in movement will be increased one-third and assumed as the actual dead load.

Wind force.

232. Top laterals—(1) bridge swinging, static wind pressure only; (2) bridge closed, ends raised, static wind pressure only.

Bottom laterals—conditions 1 and 2 (3) bridge closed, live load on one arm only ; (4) bridge closed, live load on two arms. Combine (3) or (4) with (2).

Uniform live load.

233. The stresses in the trusses of swing bridges may be calculated by an equivalent uniform live load, for a span of the length of one arm, based upon the maximum moment.

TIE PLATES AND LATTICE BARS.

Tie plates.

234. The open sides of all compression members must be stayed by tie plates at the ends and at intermediate points where the lattice is interrupted with diagonal lattice work between.

The thickness of tie plates shall not be less than $\frac{1}{50}$ of the unsupported width, unless edges are reinforced by angles ; the length on each side of intermediate chord joints shall not be less than the distance between the lines of rivets connecting them to the flanges ; at intermediate points the length shall not be less than half that distance.

Tie plates at ends of diaphragms, clause 310, page 40.

Lattice bars and rivets.

235. Single lattice bars shall have a thickness of not less than $\frac{1}{40}$th of their unsupported length. The distance between connections of the

lattice bars shall be such that the individual members composing the column, considered with pin ends and a length equal to the distance between these connections, shall be stronger than the column as a whole; in no case shall the distance exceed eight times the least width of the member, and shall not be less than the following dimensions :—

Depth of section,	6	inches,	1½	inches in width.	
"	8	"	1¾	"	
"	10	"	2¼	"	
"	12	"	2¼	"	
"	14	"	2½	"	
"	16	"	4	"	
"	18	"	4	"	
"	20	"	4	"	
"	over 20 inches, 4-inch by 3-inch angles.				

Rivets in flanges.

Five-eighths inch rivets shall be used for latticing flanges less than 2½ inches in width; ¾-inch for flanges from 2½ to 3½ inches; ⅞-inch rivets in flanges 3½ inches and over in width, and lattice bars with two rivets shall be used for flanges over 5 inches wide.

Angle of lattice.

The bars when single riveted will make an angle of 60° with the axis of member and the same angle with each other, and when double lattice an angle of 45°.

Lacing of lateral struts.

236. Top lateral struts in railway bridges, or other members composed of four angles, shall have intersecting lattice bars not less than 2½ by ⁵⁄₁₆-inch, which are to be riveted at intersection when the depth of members is 15 inches or over. Lacing between lateral struts shall be generally of angles.

REAMING, PLANING AND DRILLING.

Holes for field rivets.

237. The holes for field rivets shall be reamed or drilled from the solid to an iron template, or they shall be punched ⅛-inch smaller than the final size the parts assembled at the shop, and the holes reamed to full dimension.

Iron templates.

238. When it is impracticable to ream field connections, temporarily assembled, they will be reamed through iron templates of adequate thickness, also connections of floor beams and stringers.

Reaming tension members.

239. In tension members all punched holes shall be reamed, after the parts are assembled, to a diameter not less than ⅛-inch larger than the punch, and not more than ¹⁄₁₆-inch larger than that of the rivet, and the punch holes must match so that no less than ¹⁄₁₆-inch is removed from the die side of all holes.

Reaming compression members.

240. In compression members all punched holes shall be reamed after the parts are assembled to a diameter not less than ⅛-inch larger than that of punch and not more than ¹⁄₁₆-inch larger than the diameter of rivet.

Holes clean cut.

241. All holes must be clean cut free from torn or ragged edges. Sharp edges and burrs shall be cut off with a countersinking tool, making a fillet of about ¹⁄₁₆-inch under each rivet head.

No tapered reamers.

242. The reamers must not be tapered nor operated with a flexible shaft.

Parts clamped.

243. During reaming and drilling the assembled parts shall be firmly clamped or bolted at frequent intervals.

Secondary parts.

244. Secondary parts, such as rivet holes in lattice bars, tie plates, stiff lateral bracing and gussets, need not be reamed where soft or medium steel is used which will permit the drifting test without cracking the metal.

Lattice trusses.

245. In pony, or lattice trusses, the riveted connections of web members, and the spliced joints in tension and compression member or flanges shall be reamed after assembling.

Bolt holes.

246. When members are connected by bolts which transmit shearing stress the holes must be reamed or drilled from the solid.

Drilled holes.

247. Holes, in steel or greater thickness than ¾-inch and in the flanges of rolled beams and channels used in the floors of bridges shall be drilled. Holes in the webs of the same shall be drilled or sub punched and reamed.

Planing edges and ends.

248. All sheared edges of shapes and plates which are stressed in tension by the live load shall have, at least ⅛-inch of metal removed by planing or facing. The ends of riveted chords shall be faced after riveting except projecting splice plates.

RIVETING.

Diameter of rivets.

249. Rivets will generally be ¾-inch or ⅞-inch diameter before upsetting.

The diameter of the rivet in any angle carrying calculate stress shall not exceed one-quarter the width of the leg in which they are driven. In minor parts ⅝-inch rivets may be used in 3-inch angles and ½-inch rivets in 2½-inch angles.

Power-driven.

250. Whenever practicable rivets will be power-driven with direct acting machinery.

Heads.

251. Rivets must have hemispherical heads, be neatly cupped, concentric with the shank of rivet, of a height not less than 0·6 diameters of the rivet and be in full contact with the surface.

Holes filled.

252. Rivets must fill the holes; no loose nor badly formed rivets, caulking or recupping, will be permitted.

No drifting.

233. Rivet holes must be accurately laid off before punching. When the pieces forming a member are bolted up, the holes must match accurately so that the cold rivet can be inserted without drifting.

Rivet pitch.

234. The pitch of rivets shall not be less than 3 diameters of the rivet, for ⅞-inch rivets, nor more than 6 inches, in the line of stress, in members composed of plates and shapes, for ⅞-inch rivets and 5 inches for ¾-inch rivets.

The pitch of rivets, at the end of compression members, shall not exceed four diameters of the rivet, for a distance equal to twice the depth of the member, and in flanges of girders and chords carrying the floor the pitch shall not exceed 4 inches.

The distance between centres of rivets for plates under compression stress shall not exceed sixteen times the thickness of plate in line of stress, nor forty times the thickness at right angles to line of stress.

Edge distance.

235. The centre of a rivet shall not be nearer a sheared edge of metal than 1½ inches for ⅞-inch rivets, and 1¼ inches for ¾-inch rivets, and to a rolled edge 1¼ and 1⅛ inches respectively. The maximum distance shall be eight times the thickness of the plate, but shall not exceed 6 inches.

Net section at rivets.

236. Rivet holes in tension shall be estimated at one-eighth inch larger than the diameter of the rivet before driving.

237. In proportioning rivets, the diameter of the rivet before driving shall be used.

Dies.

238. The dies will not exceed the diameter of the punch by more than 1/16-inch.

Countersinking.

239. Countersinking must be neatly done, all holes of the same size, and countersunk rivets must completely fill the holes.

Field rivets.

240. Field riveting must be reduced to a minimum, and such rivets shall not have a greater diameter than ⅞-inch.

Rivets will not be used in direct tension, but in any case where rivets, in direct tension, may be permitted they shall be estimated at two-thirds of the unit stress.

EYE-BARS, PINS, PIN HOLES AND BOLTS.

Eye-bars upset.

241. Eye-bars shall be upset on the solid bar or rolled without welding, by mills having an established reputation for the manufacture of eye-bar steel.

Work on bars.

242. No work on the bars will be done at a blue heat, and all bars must be thoroughly annealed after forging.

Heads.

243. The heads of eye-bars shall be so proportioned that the bar will break in the body instead of the eye; they shall be clear forgings, free

from flaws and of full thickness in the necks. They shall be perfectly straight before boring. The holes shall be in the centre of head and in the centre line of bar.

Boring. 264. Bars, which are contiguous, or belonging to one parcel of the structure, shall be bored at one setting of the drills at the same temperature, they shall be of such equal length between pin holes that when they are piled upon each other the pins will pass through the holes, at both ends, without driving.

Variation of lengths. 265. In pieces not adjustable for length, no variation in length of more than 1/64-inch for every 10 feet will be permitted nor more than 1/32-inch for their entire length between centres of pin holes.

Bars parallel. 266. The bars of a set shall be laid symmetrically about centre of pin and as nearly parallel to the axis of truss as possible. The maximum allowable inclination of any bar being limited to 1 inch in 16 feet. All vacant spaces between chords and posts must be filled with wrought iron filling rings.

Pin fit. 267. Pins shall be turned straight and smooth to a gauge, and shall fit the pin holes within 1/50-inch for pins under 5 inches in diameter, and within 1/32-inch for lateral pins and pins over 5 inches in diameter. They shall be turned to a smaller diameter at the ends and driven in place with a pilot nut. There will be a washer for adjustment under at least one nut unless recessed nuts are used.

Pin centres. 268. Pin centres will be in the centre of gravity of the members, less the eccentricity required to provide for their own weight, and in continuous chords pin centres will be in the same plane.

Pin holes. 269. Pin holes must be bored truly parallel with each other and perfectly square with the member. They shall be bored with a sharp tool and a finishing cut will always be taken. The finished pin hole shall be perfectly smooth. The play in the pin holes shall never exceed 1/50-inch for pins up to 5 inches in diameter and 1/32-inch for pins over 5 inches in diameter.

Reinforce plates. 270. In pin holes, reinforced by plates, the pressure will not exceed the allowed pressure on pins.

The reinforce plates must contain enough rivets to transfer a part of the bearing pressure, and at least one plate on each side shall extend not less than 6 inches beyond the edge of the furthest batter plate.

Bolt heads nuts. 271. Bolts will have hexagonal heads and nuts. Round headed bolts will not be used. Wrought iron or steel washers will be used when the heads or nuts of bolts bear upon wood.

272. Bolts shall not be used in the place of rivets, except by especial permission.

Bolts.

273. When members are connected by bolts that transmit shearing stress the holes must be reamed or drilled from the solid and the bolts machine-fitted to fill the holes with a driving fit. A washer not less than ¼ inch thick shall be used under the nuts.

Anchor bolts.

274. The ends of bridges shall be anchored to masonry by fox bolts, which shall not be less than 1¼ inch diameter for trusses, and enter the masonry at least 12 inches, and placed not nearer than 6 inches from face of masonry under the coping. Anchor bolts for viaduct towers and similar structures shall be long enough to engage a mass of masonry the weight of which is at least one and one-half times the estimated tensile stress upon the anchor.

The contractor must furnish all bolts, drill all holes and set bolts with sulphur or cement.

SHOES, BED PLATES, &c.

Bed plates.

275. There shall be provided pier boxes, or plates of approved form, under pedestal shoes at both ends, of sufficient depth to distribute the weight properly on the masonry.

Thickness of plates.

276. The plates, or boxes, shall have a minimum thickness of ¾ inch for trusses, and must have planed surfaces and be of such dimensions that the greatest pressure per square inch on the masonry shall not exceed that specified.

Sheet lead.

277. Sheet lead, not less than ¼-inch, shall be placed between the plates and all bearings on masonry, when directed by the Engineer.

Continuous plate.

278. Two spans rest upon the same pier, if specified, a continuous plate of not less than ¾-inch thick will extend under the two adjacent bearings.

Bearings.

279. Bed plates and bearings must be fox-bolted to the masonry, the fixed ends to be held rigidly, and the sliding ends, while free to move longitudinally, must be fixed against lifting or sliding motion.

Friction rollers.

280. All bridges, over 80 feet span, will have, preferably, hinged bolsters at both ends and a nest of turned friction rollers at one end bearing upon planed surfaces; they shall be protected against the entrance of dirt, and shall not be boxed in so as to retain the water. Their motion shall be guided in an efficient manner, and they shall be coupled together with substantial side bars so arranged that the rollers can be readily cleaned.

Size of Rollers

The rollers shall not be less than 5 inches diameter and proportioned so that the pressure shall not exceed the roller unit stress specified.

Rollers shall be turned and sliding surfaces of all plates and bearings planed.

Friction plates.

281. Under 80 feet span at one end there will be friction plates which will be free to move on a planed surface.

LATERAL BRACING.

Stiff laterals.

282. The top lateral struts, preferably, will be the full depth of the chord and will be securely riveted thereto. Top lateral bracing will be stiff and in spans of 200 feet and over it will consist of angles latticed.

Posts to resist bending.

283. The attachment of the lateral system to chords must be entirely efficient. If connected above or below the main chords the posts must be proportioned to resist the bending induced by the horizontal component of the lateral.

Lateral bracing.

284. Lateral, longitudinal and transverse bracing will resist both compression and tension.

Knee and portal bracing.

285. Knee-braces will be used at the portals and at each panel point and shall be designed to form rigid and efficient connection between top lateral struts and the posts.

When there is sufficient head-room substruts and sway frames will be provided.

Portals will be as deep as head-room will permit and will consist of struts latticed with angles, rigidly connected to the end posts and top chords.

Bracing of deck bridges.

286. In decked bridges transverse bracing will be provided at each panel; the transverse bracing at the ends shall be of the same equivalent strength as the end top lateral bracing. The bracing must in all cases clear the ties.

Intersecting members.

287. Each panel of bracing will, preferably, consist of two intersecting members, securely riveted at their intersection.

Size of angles.

288. The minimum sized angle in lateral bracing will be 3½ by 3 by ⅜-inch. Not less than four rivets through the ends of the angles shall be used at the connections.

JOINTS, SPLICES AND CONNECTIONS.

Joints.

289. Joints, in riveted work, whether in tension or compression must be fully spliced, their abutting ends shall be dressed straight and true. The sections of compression chords will be connected at the abutting ends by splices sufficiently strong to hold them in true position.

Abutting ends must be brought into close contact when fitted with splice plates, and the rivet holes reamed in position before leaving the works, all pieces being match-marked for erection.

Rivets and plates.

290. Web plates will be fully spliced for bending and shear; in no case shall there be less than two rows of rivets on each side of joint.

Sections of top chords of railway bridges shall be connected at abutting ends by side plates, having at least six rivets in each plate on each side of joint.

291. When the ties rest directly on chords the splice shall make good the section required for bending, the side splices being proportioned to take up the maximum shear (chord considered as a simple beam) at end of panel, and the top and bottom splices each to take the maximum bending stress occurring at any point of panel.

Splices with ties on top chords.

292. When the compression members are forked, to connect to the pins, the compressive strength of the ends must equal the compressive strength of the body of the member.

Forked compression members.

293. The ends of all members which make contact joints shall be planed smooth, to exact angle with axis of member.

Contact joints.

294. Single angles must be connected by both legs or else the section of one leg only will be considered effective.

Single angle connections.

295. Turnbuckles and clevises must develop the strength of the members connected.

Turnbuckles and clevises.

296. Whenever it is necessary to reinforce metal about pin holes or joints, the reinforce plate shall lap over the flange angle of the member at hips or shoes.

Reinforce plates.

297. Care must be exercised in the design of riveted tension members; those with pin hole connections will have, in net area of section, through the pin hole, an excess of strength of 50 per cent over the net area of member, and the net area back of pin hole must be equal to the net area of the member.

Net area about pin holes.

298. In members the rivets shall be symmetrically arranged from the centre line. Eccentricity of stress shall be avoided in all riveted connections.

Rivets.

299. In intermediate posts both web and pin plates will extend beyond pin hole a length at least equal to the diameter of pin hole.

Web and pin plates.

300. When the flanges of posts, or struts, are cut to clear eye-bars the posts cut must be reinforced either by a diaphragm or plates extending at least 6 inches beyond the cut, and of sufficient section to develop the full strength of the member. Such cuts shall be avoided whenever possible.

Diaphragms and plates.

CONSTRUCTION AND WORKMANSHIP.

301. Unsymmetrical sections composed of two rolled or riveted channels and one plate, shall, in chords, be so proportioned that the centre of pins in abutting members shall be in the same line and in the centre of gravity of the section.

Centre of pins, centre of gravity.

302. Details which will be most accessible for inspection, cleaning and painting will be preferred and they must be of a design satisfactory to the Engineer.

Details accessible.

Limiting sections

303. No material shall have a less thickness than ⅜-inch in railway bridges, whether in plates or shapes, except lattice bars, stiffeners or wind bracings; the latter shall not be less than 3 by 2½ by $\frac{5}{16}$-inch angles.

In through railway pin connected bridges no posts, channels whether built or rolled, shall be less than 10 inches. No angle less than 2½ inches by 3 by ⅜ inches will be used in girders or truss members, or in any member having ⅞-inch rivets.

No angles less than 3 inches by 2½ inches by $\frac{5}{16}$-inch will be used in any part of the structure.

No lateral or diagonal rod shall have a less area than 1 inch square.

The splice plates on chords and end posts will be at least ⅜-inch thick.

Length angles

304. Angles, covered plates and web sheets, will be as long as practicable to avoid splicing.

Construction of upper chords and end posts

305. Upper chord and end posts will consist of built or rolled channels and sufficient metal will be concentrated at the bottom so that the centre of gravity will be near the centre of web-plates. They will have, preferably, a cover plate, which if specified by the Engineer may not be considered as area of cross sections.

Unsupported width of plate

306. The unsupported width of any plate, subjected to compression, shall never exceed thirty times its thickness, excepting cover plates of top chords and end posts, when it may be forty times its thickness.

Hip hangers

307. In through trusses the end posts must be battered. End vertical suspenders or hip hangers will be stiff members and stand vertical.

End panels stiff members.

308. Spans with bottom chords of eye-bars will have stiff members in the two end panels at each end of span.

Members, clamped.

309. Long intersecting members in tension shall be clamped together to prevent rattling.

Diaphragm between channels

310. Vertical posts, made up of two channels, the pins passing through the webs, the flange sides being turned in, shall have the end reaction of the floor beams transferred to both segments by a diaphragm or side plates. When diaphragms are used tie plates will be required at each end of diaphragm, their length to be not less than the width of the member.

Bending in posts

311. Due allowance must be made for the bending in posts induced by the portal bracing and sway struts and rods.

Chord sections

312. In compression chord sections the material must be well concentrated at the side.

Workmanship.

313. All workmanship must be first-class. Shearing shall be neatly and accurately done, and all parts of the work exposed to view truly

finished. The ends of floor beams and stringers when framed in shall be squared in the lathe. The end angles must be faced so that the facing does not reduce the thickness of the angles by more than one-eighth of their original thickness. The cut shall extend over the whole thickness of the angles.

Heating beams.

314. Heating beams to cut them will not be allowed and no patched beams will be accepted.

Close fit.

315. The several pieces, forming built-up members, must fit closely together without open joints, especially pin-bearing chords and end posts.

Members and holes.

316. All members must be straight and out of wind; holes accurately bored, both in position and direction; lengths correct within 1-32-inch and within 1/64-inch for all pieces of the same set.

Material straightened.

317. All material must be straightened before being laid off, also after punching and before assembling. The templates must lay flat without distortion while marking is being made.

Lodgment of water.

318. Places where water will lodge will be drained or filled with waterproof material.

Camber and camber lengths.

319. All bridges, of 80 feet span and over, shall be cambered by making the panel lengths of upper chord longer than the lower chord in the proportion of ⅛-inch in 10 feet, if not otherwise specified.

The increased length of top chord shall be neglected in computing the lengths of main ties, but considered when computing lengths of inclined end posts and counter braces.

QUALITY OF MATERIAL.

WROUGHT IRON.

Quality.

320. All wrought iron where permitted to be used must be tough, ductile, fibrous and of uniform quality for each class, free from blisters, cinder spots, buckles, flaws, or cracks along the edges, and must be thoroughly welded during the rolling.

Tests.

321. Test pieces cut from finished material shall show an ultimate tensile strength of not less than 50,000 pounds per square inch, an elastic limit of not less than 26,000 pounds per square inch and an elongation of not less than 20 per cent in 8 inches.

It must bend cold 180 degrees without sign of fracture to a curve whose diameter is equal to twice the thickness of test piece. Test pieces when nicked and broken shall show a fibrous fracture of at least 90 per cent.

Unit stress.

322. The unit stress will be 20 per cent less than medium steel.

STEEL.

[illegible]

323. All steel shall be made, at works of established reputation, by either the acid or basic open hearth process. It shall be of uniform quality, tough and ductile. Bessemer steel shall not be used in any structure.

Finished material.

324. All finished material shall be free from piping, checks cracks, flaws, blisters, or other imperfections ; it shall have a smooth finish on edges, a clean surface, and shall be true to section.

Plates rolled edges.

325. Plates 36 inches in width and under shall have rolled edges.

Tests by melts.

326. A copy, of all tests, analyses and inspection of every melt made as prescribed in these specifications, shall be furnished the inspector, who will be appointed before the work commences by the Engineer, and whose services shall be paid for by the Contractor.

Melt numbers shall be clearly stamped hot on all finished material rolled from the melts, and omissions to do so, or changes and confusion of the melt numbers, may be causes for rejection of the material.

Rejection of material, if the tests at the mill are not satisfactory shall go by melts, excepting when the local character of the defects can be clearly proven.

Surface defects.

327. Blooms, billets, or slabs will be examined for surface defects, flaws, or blow holes.

Test pieces, yield point.

328. The tensile tests for yield point, ductility and ultimate strength will be determined from standard test pieces not less than 10 inches long, of at least one-half square inch section.

Test pieces from material.

329. The test pieces shall be taken from material rolled at a uniform heat. It shall not be permitted ; after rejection of material, to roll at a special heat to meet the requirements of the specification.

Inspector requires.

330. The test pieces shall be cut from the finished material as required by the Inspector.

Contractor, at his cost.

331. The Contractor shall furnish, at his own cost, from each melt, at least two bending and two tension test pieces and such drifting test pieces as the Inspector may require, also the labour and tools necessary to make the tests, and if the requirements are not complied with such additional test pieces as may be required by him will be furnished.

Appearance broken.

332. Test pieces, when broken in the machine, must show, at the fracture, a uniform fine grain of a fine silkish blue gray appearance, free from granular spots, coarse crystals, and should be entirely free from brilliant specks.

Requirements.

333. The steel which will enter into the construction of any structure erected under this specification, shall fully meet the following requirements :—

334. The percentage of elongation shall be determined from the test pieces after breaking on an original length of 8 inches, which length must include the curve of reduction from the elongation on both sides of the point of fracture. Elongation, how determined.

QUALITIES OF OPEN HEARTH STEEL

Shapes.	Ultimate tensile strength Lbs. per sq. inch.		Elastic limit, percentage of ultimate.	Elongation, percentage in 8 inches.	Reduction of area per cent.	Chemical requirements.				
						Phosphorus		Sulphur		
	Min.	Max.				Acid.	Basic.	Acid.	Basic.	Man-ganese.
Rivets	48,000	58,000	50	1,500,000 / ultimate	60	0.04	0.04	0.04	0.04	0.60
Angles and bars	56,000	66,000	50		50	0.10	0.04	0.05	0.05	0.60
Plates	56,000	66,000	50		50	0.10	0.04	0.05	0.05	0.60
Flanges of—										
Beams and channels	56,000	66,000	50		45	0.07	0.04	0.05	0.05	0.60
Eye bars, acid steel	60,000	70,000	50		45	0.06	—	0.04	—	0.60
" basic "	60,000	70,000	50		45		0.04		0.05	0.60
Pins	64,000		50		40	0.06	0.04	0.05	0.05	0.60
Cast steel	65,000		50	20 in 2 inches		0.08	0.04	0.05	0.05	0.60

336. The chemical requirements shall be determined from a test ingot taken at the time of pouring off each melt of steel, and a correct copy of such analysis shall be furnished the Engineer or his Inspector. Chemical analysis, ingots.

337. Check analysis shall be made from the finished material if called for by the purchaser, in which case, an excess of 25 per cent above the required limits will be allowed. Chemical analysis, finished material.

338. Test pieces cut from finished eye-bars shall meet the above requirements, except specimens from bars over 1½ inches thick shall show not less than 20 per cent elongation. Test pieces of eye-bars.

339. Test pieces of medium steel must bend cold, or after being heated, to a red heat and cooled in water 72° Fah., 180 degrees around a circle whose diameter is equal to the thickness of the test piece, without signs of cracking. Tests, cold bending.

Test pieces of soft steel and rivet steel must bend cold, or after being heated and cooled in water 72° Fah., 180 degrees flat upon themselves without signs of cracking.

340. Rivet rods or finished rivets, when heated cherry red and cooled in water of a temperature of 72° Fah., shall bend double to close contact without showing sign of fracture on the outer side of bend. Tests, rivet rods.

Tests, angles.

341. All angles shall open flat, and angles ⅝-inch and less in thickness will bend cold shut under the blows of a hammer without signs of fracture.

Drifting.

342. Punched holes pitched two diameters from a sheared edge will permit cold drifting, until they are expanded to one and one-half times their original diameter, without cracking the sides of the metal.

Rejected material.

343. All material shall successfully bear every test similar to those to which it may be subjected during the process of manufacture and in demonstrating its ductility and toughness. Any material which does not come up to the standard of these specifications, as described, shall be rejected, and it shall not enter into the construction of the structure.

Failure in shop.

344. All material, which, subsequently to the tests at the mill and to its acceptance there, during manipulation, in the shops under shears, punch, &c., which shows it is not of uniform quality, as herein specified, and also hard spots, brittleness, cracks and other defects are developed; such material shall be rejected and shall be replaced by the Contractor with material which shall conform to the conditions of this specification; and it is expressly understood that mill inspection and acceptance does not bar the right of the Engineer, or his representative, to reject in the shop any material which proves to be defective or inferior in quality and uniformity to the material herein specified.

Slabs from ingots.

345. The slabs for rolling plates shall be hammered, or rolled, from ingots from which the scrap has been cut off; the ingots shall be double the cross sectional area of the slab.

Eye-bars from ingots.

346. Eye-bars shall be rolled from ingots at least 25 per cent of the top cut off and exhibit no piping. The bars shall be rolled down in one heat from the bloom which shall be of sufficient thickness to insure the proper amount of work in rolling and the proper finishing temperature.

Test pieces from eye-bars.

347. Tests pieces shall be taken from the sides and centre of bars, and tested, annealed and unannealed; the cold unannealed bending tests shall be made on pieces the full thickness of the bar.

Members tested to destruction.

348. Material, in full sized members if not in exceptional shapes or sizes, tested to destruction, is intended to develop the full strength, required of the material above specified for test pieces both as to elastic limit and ultimate strength. Elongation of full sized members may vary with their length, but shall not fall below 12½ per cent.

Heated members annealed.

349. All members, wholly or partly heated in working, except offset stiffeners, or bent cold, shall afterwards be carefully annealed, and no sharp or unfilleted corners shall be allowed.

Pins rolled and forged.

350. Pins up to 7 inches in diameter will be rolled.

Pins exceeding 7 inches in diameter shall be forged under a steam hammer striking a blow of at least 5 tons. The blooms shall have at least three times the sectional area of the finished pin.

351. No forging shall be done under red heat and the rounds must be true, straight and free from flaws or cracks.

No forging under red heat.

352. Material, other than plates, varying more than 2½ per cent from the scantling ordered and imperfectly rolled shapes will be rejected. All plates must be rolled to full gauge thickness at the edges.

Variation in sections.

TEST OF EYE-BARS.

353. Full sized eye-bars, of medium steel tested to destruction, shall have an ultimate tensile strength of not less than 58,000 pounds per square inch for bars 9 square inches and less in section, and 56,000 per square inch for bars in excess of the above area; an elastic limit of not less than one-half the ultimate strength of the bar. They shall elongate 10 per cent of their full length and 12½ per cent in a gauged length of 15 feet, which shall include the point of fracture in the bar.

Eye-bars tested to destruction.

354. All fractures shall show more than 80 per cent silky, and be free from granular spots. A dull fracture will be considered a failure of test.

Fracture appearance of.

355. Notice will be given as to the number and size of eye-bars to be tested to destruction. The material will be rolled at the same time as that required for the structure. The number of tests of eye-bars will depend upon the number of bars in the structure. There shall be, at least, two eye-bars for a single span and about three per cent for a small number of bars.

Number of test eye-bars.

For a large number of bars about two per cent will be tested. If in these tests the bars prove uniform in strength, ductility and elasticity, and comply in every way with the requirements of the specification, the Engineer may reduce the number of tests.

356. Long bars taken at random from a number of finished bars may be cut in two and upset at the cut ends and each piece tested.

Long bars may be cut.

357. Bars which break in the eye, and comply with the requirements of the body of the bar, will not be cause for rejection of any lot of bars unless one-quarter of the bars tested break in the eye.

Bars which break in the eye.

CAST STEEL.

358. Steel castings shall be made of acid open hearth steel and shall conform to requirements previously specified.

Steel castings.

All castings shall be true to patterns, free from pouring faults, shrinkage, cracks, waste sponginess, excessive sand pits or injurious blow holes.

359. Finished castings shall be practically free from blow-holes with their surfaces reasonably clear and smooth in finish.

Finished castings.

Runners for testing.

360. Steel castings will be tested for strength and ductility from runners cast with the pieces and annealed with the casting; such runners will be turned down to not less than one half square inch section for a length of about 6 inches. They shall bend cold at right angles on a round corner to a radius of the diameter of the test piece.

361. Steel castings shall be uniformly annealed.

CAST-IRON.

Steel castings annealed.

362. Except where chilled iron is required, all castings shall be of tough gray iron with not over 0·10 of sulphur. They shall be free from injurious blow-holes, cold shuts, true to pattern and thickness, and of workmanlike finish.

Requirements cast iron.

363. Sample pieces, 1 inch square, cast from the same heat of metal in sand moulds shall be capable of sustaining on a clear span of 4½ feet, a central load of 500 pounds when tested in the rough bar.

Test pieces.

Three test bars must be furnished by the Contractor from every heat, which, if upon testing, they do not stand the specified test, all castings made from that heat of metal will be rejected.

Blow from hammer.

364. A blow from a hammer shall produce an indentation, on a rectangular edge of the casting, without flaking the metal.

TIMBER.

365. Timber shall be first-class oak, white pine, red or Norway pine, Georgia yellow pine, British Columbia 'Douglas' Fir, spruce, tamarack, it shall be sawn true and out of wind, free from wind shakes, large or loose knots, decayed or sap wood, worm holes or other defects impairing its strength or durability.

PAINTING, CREOSOTING AND ASPHALT.

Metal cleaned.

366. Before painting, all metal surfaces shall be thoroughly scraped and cleaned of all rust, scales or dust, either with sand blast, steel scrapers or stiff wire brushes, and finally dust off surfaces with a stiff bristle brush.

367. If not otherwise specified the paint used for shop priming coat, will be pure red lead and lampblack, mixed with raw linseed oil. It shall not be thinned with turpentine, benzine or other liquids, and no dryer will be allowed. The red lead and lampblack will be mixed dry, the linseed oil added, the mixture stirred to a uniform consistency and applied at once. Each gallon of paint will contain 12 pounds of red lead and 10 oz. of lampblack; only a sufficient quantity for immediate use shall be mixed at once.

Surfaces inaccessible and planed work.

368. All surfaces, inaccessible after erection, shall have two coats of paint and all planed or turned surfaces shall be cleaned and coated with white lead mixed with tallow before leaving the shops.

In riveted work the surfaces in contact shall be painted before being riveted together.

Field coats.

369. The field coats will be iron oxide, or such other paint, as may be specified by the Engineer.

Paint in barrels.

370. Paint shipped in barrels for field purposes must be prevented from setting by frequent shaking.

Metal cleaned after erection.

371. After the erection of the structure, all rust spots must be thoroughly cleaned, where the paint is rubbed off edges, rivet, nut and bolt heads, they must be painted.

Number of coats.

372. When dry the structure shall receive two coats of paint.

All three coats will be of a different shade of colour if so directed.

White paint, canals.

373. Upon the canals and when preferred by the Engineer if a white colour is desired, it will be of a mixture of white lead and zinc.

Wet weather.

374. No painting will be allowed in wet or freezing weather. All painting must be done by skilled workmen.

Wood, coat of hot tar.

375. Cross ties, guard rails, or any surfaces of wood in contact with wood or iron, and countersunk holes for bolts and washers, will be painted with hot tar thickened with lime, or with paint.

Creosoting.

376. When the contract includes creosoted timber it will be thoroughly seasoned at a temperature not exceeding 250 degrees Fah. in a vacuum of 24 inches of mercury and not less than ten pounds of heavy creosote oil to each cubic foot of timber shall be forced into the timber under a pressure of not less than 150 pounds per square inch.

Creosote oil.

377. Creosote oil shall contain not less than five per cent of tar acids and not less than twenty-five per cent of ingredients that do not distill over at a temperature of 600 degrees Fah. It shall generally be solid at a temperature of 50 degrees Fah. and entirely liquid at a temperature of 100 degrees Fah. It shall be free from water, ammonia, naptha and any other impurities.

Asphalt concrete.

378. Through solid girder trough floors, or where specified, will have a coat of pure asphalt upon the metal and then covered with asphalt concrete of one part asphalt, two parts sand and three parts limestone screenings thoroughly mixed and rammed into place with tamping iron.

Quality of asphalt.

379. Asphalt shall be of the best quality free from coal tar or its products; it will not volatilize more than one-half of one per cent under a temperature of 300° Fah. for ten hours.

For underground structures a flow point of 185° Fah. and a brittle point 6° Fah. below zero will be required.

ERECTION AND GENERAL.

Care of material.

380. The material, for the structure after and previous to delivery, shall be kept clean and so handled and stored that injury to any piece will be avoided.

Interference.

381. The Contractor must conduct operations so as not to interfere with the navigation of, or works of the canal or river, the operation of the railway or close any thoroughfare by land or water.

382. The Contractor must furnish all necessary false-works and remove them after completion of structure.

Risk.

383. The Contractor shall assume all risk from floods, storms and casualties of every description, and must furnish all material and labour incidental to, or in any way connected, with the manufacture, erection and maintenance of the structure until its final acceptance.

Patented parts.

384. If patented parts are used the Contractor shall protect the government against any or all claims on account of the use of such patent.

Inspection.

385. The Engineer, or any inspector appointed by him, shall have every facility for testing and inspection of material and workmanship, he shall, at all times, have access to any part of the mills, in which any of the material is manufactured or work performed, and said Engineer, or any inspector appointed by him, shall have direct supervision, at all hours of all material, shopwork and erection ; he shall have power to reject all work which in his opinion does not conform to this specification.

Payment for members test.

386. When members of a structure are tested to destruction if they fulfil the conditions of this specification, they shall be paid for at cost less scrap value, if they do not fulfil the conditions the Contractor shall bear the cost.

Train load tests.

387. Before the acceptance of the structure, the Engineer may make a thorough test by passing over it the specified train loads at a speed not exceeding thirty miles per hour, and bringing to a stop at any point by means of air or other brakes, or by resting the maximum load upon the structure for such period of time as he may think proper.

Set after test.

388. After tests the structure shall show no permanent set or change in any of the members.

Work fully executed.

389. It is hereby fully understood, that, anything necessary to the full and complete execution of the work according to the general intent and meaning of the drawings and specifications, is to be done, and all materials are to be furnished, so as to fully execute the work in a workmanlike manner, whether herein particularly described or not.

Omissions in drawings and specifications.

390. Should anything appear to be omitted, or errors occur, in either drawings or specifications or both, which may be necessary to the proper performance and completion of the work, the Contractor shall take no ad-

vantage of the same, but supply whatever may be wanting as though it had been particularly described.

291. No allowance of over 2 per cent of the total weight of the structure, as calculated from the plans, will be made for excess weight in pound price, contracts by scale weights.

Scale weights pound price.

292. In case of any alteration, additions or deduction, the price shall be agreed upon in writing before such work is performed, and no extras shall be allowed unless first agreed upon in writing and the price fixed.

Extras.

293. The whole work to be done to the full and entire satisfaction of the Engineer, who shall have power to reject any part or portion of the work not in strict accordance with the specifications and the drawings referred to.

Inspection of work.

294. The word 'Engineer' as used in this specification refers to the Chief Engineer of the Department of Railways and Canals, or to his assistant, the Bridge Engineer of that Department.

Engineer defined.

295. All the materials must be of the best class of their respective kind, and the prices tendered for the several items of work must cover the entire cost of their purchase, delivery, workmanship and every contingency connected with the due prosecution of the work as herein described and the instructions of the Engineer.

Prices tendered to cover entire cost.

296. Tenders on all work for the Government of Canada will not be considered unless made strictly in accordance with the printed forms, and in the case of firms except there are attached the actual signatures, the nature of the occupation and the place of residence of each member of the same.

Tenders.

297. For the due fulfilment of the contract on all work done for the Government of Canada satisfactory security will be required by a deposit of money, to an amount of ten per cent on the bulk sum of contract.

Security and deposits.

ROBERT C. DOUGLAS,
Hydraulic and Bridge Engineer.

DEPARTMENT OF RAILWAYS AND CANALS.

LIST OF DIAGRAMS AND TABLES

A—Standard Clearance, Railway Bridges.
B—Standard Loading for Railway Bridge.
C—Conventional Signs for Rivets.

Table No.
1. Maximum Moments, Shears, &c.
2. Stress in Compression Numbered Clause 142.
3. Maximum Bending Moments on Pins, Clause 146.
4. Shearing and Bearing Value of Rivets, Highway Bridges.
5. Shearing and Bearing Value of Rivets, Railway Bridges.
6. Deductions for Rivet Holes.
7. Table for proportioning Gear and Rack Teeth.
8. Sizes of Railway Bridge Ties.
9. Decimals of an inch and Decimals of a Foot.
10. Bending Moments and Deflection of Beams.

DIAGRAM A.

STANDARD CLEARANCE & FLOORING OF RAILWAY BRIDGES

Department of Railways & Canals

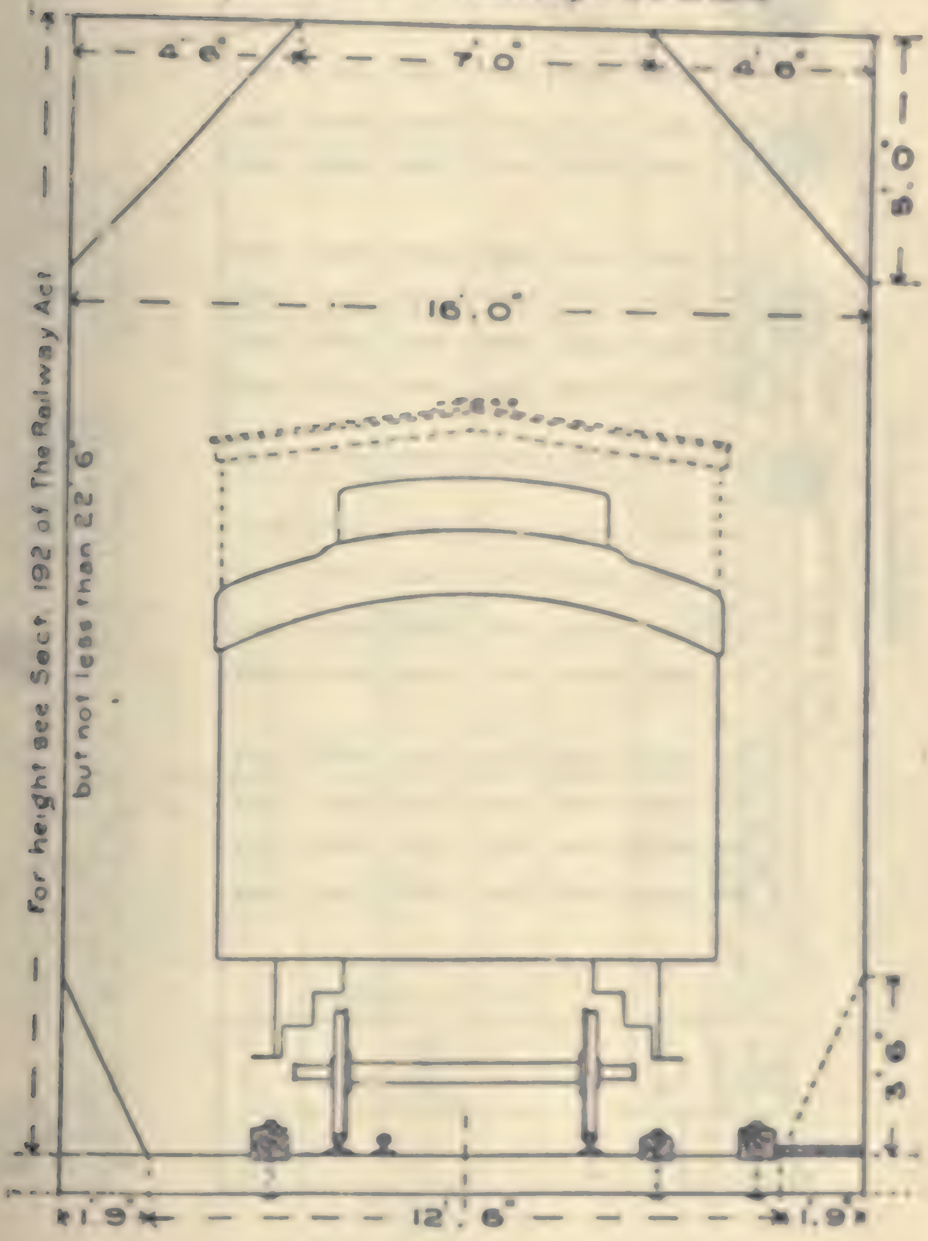
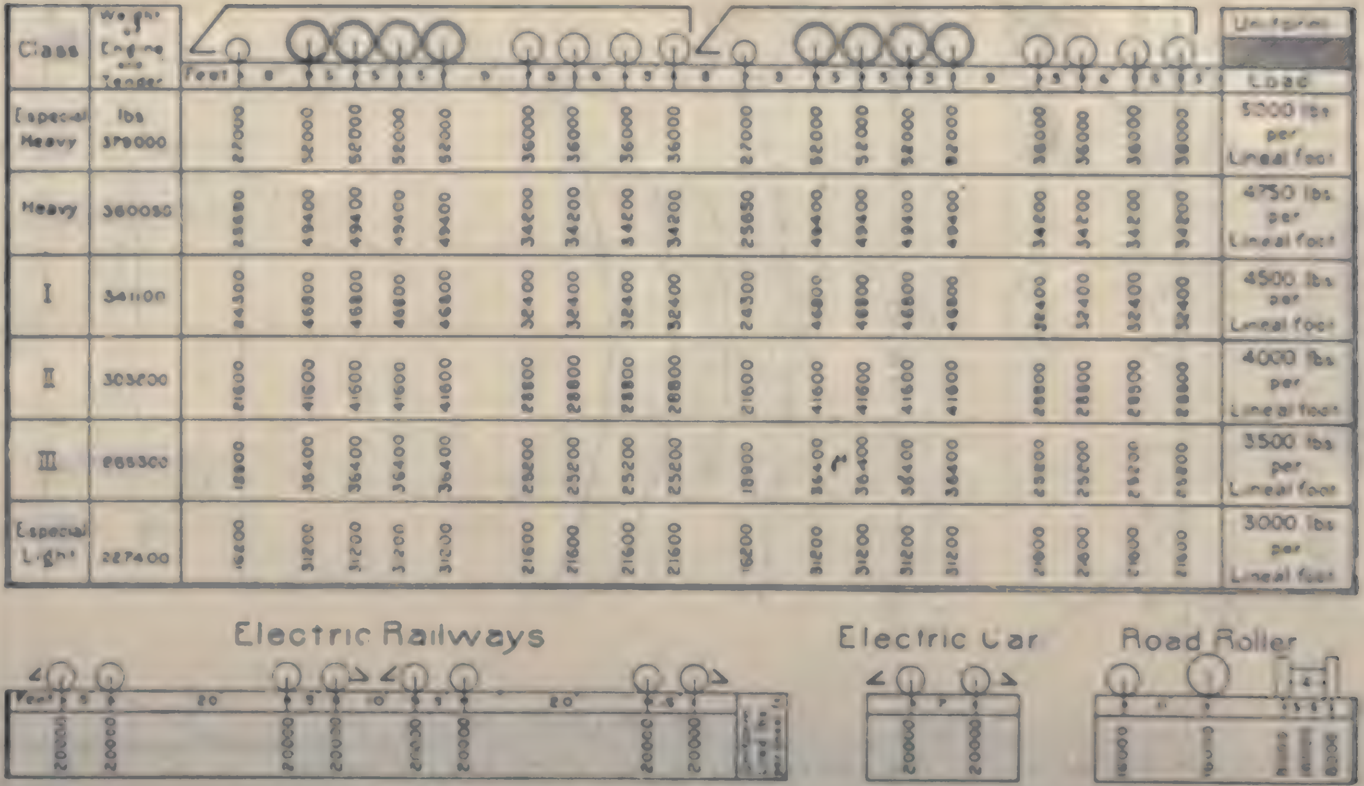


DIAGRAM B.

Standard Loading of the Department of Railways & Canals,
Steam Railways, 1905.



Class	Weight of Engine and Tender																			Uniform Load
Especial Heavy	lbs 379000	27000	52000	52000	52000	52000	36000	36000	36000	36000	27000	52000	52000	52000	52000	36000	36000	36000	36000	5000 lbs per Lineal foot
Heavy	360050	25650	49400	49400	49400	49400	34200	34200	34200	34200	25650	49400	49400	49400	49400	34200	34200	34200	34200	4750 lbs. per Lineal foot
I	341100	24300	46800	46800	46800	46800	32400	32400	32400	32400	24300	46800	46800	46800	46800	32400	32400	32400	32400	4500 lbs per Lineal foot
II	303200	21600	41600	41600	41600	41600	28800	28800	28800	28800	21600	41600	41600	41600	41600	28800	28800	28900	28800	4000 lbs per Lineal foot
III	265300	18900	36400	36400	36400	36400	25200	25200	25200	25200	18900	36400	36400	36400	36400	25200	25200	25200	25200	3500 lbs per Lineal foot
Especial Light	227400	16200	31200	31200	31200	31200	21600	21600	21600	21600	16200	31200	31200	31200	31200	21600	21600	21600	21600	3000 lbs per Lineal foot

DIAGRAM C

CONVENTIONAL SIGNS FOR RIVETING.

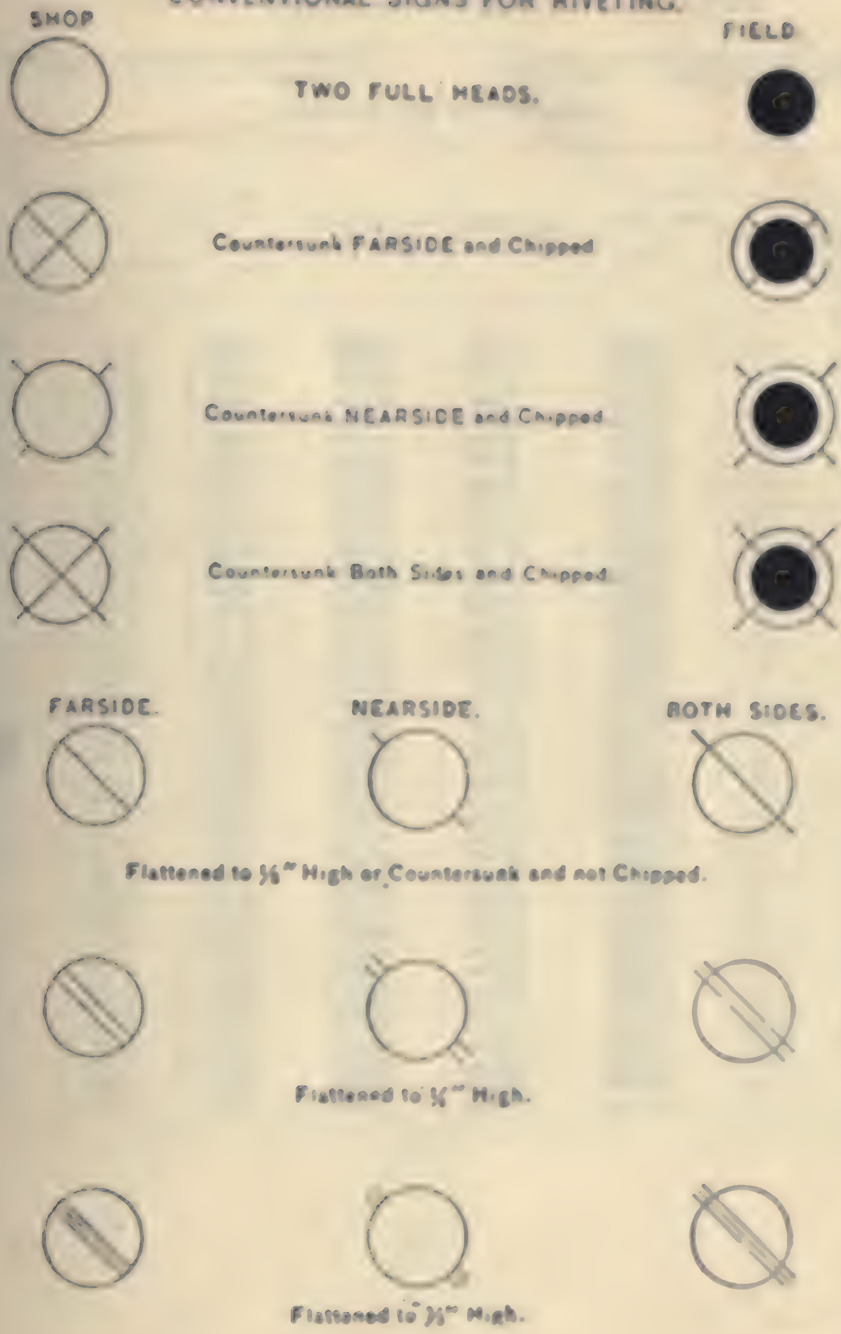

SHOP
FIELD
TWO FULL HEADS.
Countersunk FARSIDE and Chipped
Countersunk NEARSIDE and Chipped
Countersunk Both Sides and Chipped
FARSIDE.
NEARSIDE.
BOTH SIDES.
Flattened to ⅛" High or Countersunk and not Chipped.
Flattened to ¼" High.
Flattened to ⅜" High.

TABLE I.

MAXIMUM Moments, Shears and Floor-beam Re-actions Produced by Standard Loading CLASS II. of the Department of Railways and Canals, 1905.

These figures are exclusive of factor $1.40 - \frac{L}{300}$ specified in clause 146.

Figures for other classes are proportional to this table in ratio of uniform train loads.

FIGURES FOR TWO RAILS.

Span in Lineal Feet.	Max. Mom. in ft. lbs.	Max. End. Shear.	Max. Fl. Bm. Reaction.	EQUIVALENT UNIFORM LOAD.		
				Mom.	End Shear.	Fl. Bm. Reaction.
10	117,000	62,400	83,200	9,360	12,480	8,320
11	136,600	68,100	90,700	9,030	12,380	8,250
12	166,400	72,800	97,100	9,250	12,140	8,090
13	197,600	76,800	102,400	9,350	11,820	7,880
14	228,800	80,200	108,500	9,340	11,460	7,750
15	260,000	83,200	113,800	9,240	11,100	7,590
16	291,200	88,400	118,500	9,100	11,050	7,410
17	322,400	93,000	122,500	8,930	10,940	7,210
18	353,600	97,000	126,600	8,730	10,780	7,030
19	388,000	100,800	131,400	8,610	10,610	6,920
20	429,000	104,000	137,000	8,580	10,400	6,850
21	470,000	107,000	142,200	8,530	10,190	6,770
22	511,000	109,600	146,900	8,450	9,960	6,680
23	552,100	112,300	151,200	8,350	9,760	6,570
24	593,200	115,400	155,100	8,240	9,620	6,460
25	634,400	118,200	158,800	8,120	9,460	6,350
26	675,600	120,900	163,200	8,000	9,300	6,280
27	716,800	123,400	168,400	7,870	9,140	6,240
28	760,400	126,000	173,200	7,760	9,000	6,190
29	807,400	128,400	177,700	7,680	8,860	6,130
30	854,400	131,500	181,900	7,600	8,770	6,060
31	901,400	134,300	186,700	7,500	8,660	6,020
32	948,400	137,300	192,100	7,410	8,580	6,000
33	995,300	140,000	197,300	7,310	8,490	5,980
34	1,042,300	142,400	202,100	7,210	8,380	5,940
35	1,089,400	144,700	206,600	7,120	8,270	5,900
36	1,144,200	147,700	211,000	7,060	8,210	5,860
37	1,198,300	150,600	215,200	7,000	8,140	5,820
38	1,252,300	153,300	220,000	6,940	8,070	5,790
39	1,309,000	155,900	224,700	6,890	8,000	5,760
40	1,370,400	158,200	229,300	6,850	7,910	5,730
41	1,431,800	161,300	234,000	6,810	7,870	5,710
42	1,493,200	164,100	238,700	6,770	7,810	5,680
43	1,554,600	166,800	243,000	6,730	7,760	5,650
44	1,616,000	169,500	247,700	6,680	7,710	5,630
45	1,677,400	172,000	252,400	6,630	7,650	5,610
46	1,738,800	174,400	256,900	6,570	7,580	5,580
47	1,800,200	176,800	261,300	6,520	7,520	5,560
48	1,861,600	179,200	265,800	6,460	7,470	5,540
49	1,923,000	181,600	269,900	6,410	7,410	5,510
50	1,984,400	183,900	274,500	6,350	7,360	5,490

TABLE I.

MAXIMUM MOMENTS, SHEARS AND FLOOR-BEAM REACTIONS PRODUCED BY STANDARD LOADING CLASS II. OF THE DEPARTMENT OF RAILWAYS AND CANALS, [illegible]

These figures are exclusive of Impact $1 \cdot 40 - \frac{l}{300}$ specified in Clause [illegible]. Figures for other classes are proportional to this table in ratio of uniform static loads.

FIGURES FOR TWO RAILS

Span in Lineal Feet	Max. Mom. in ft. lbs.	Max. End Shear	Max. Fl. Bm. Reaction	Equivalent Uniform Load		
				Mom.	End Shear	Fl. Bm. Reaction
52	[illegible]	[illegible]		[illegible]	[illegible]	
54	[illegible]	[illegible]		[illegible]	[illegible]	
56	[illegible]	[illegible]		[illegible]	[illegible]	
58	[illegible]	[illegible]		[illegible]	[illegible]	
60	[illegible]	[illegible]		[illegible]	[illegible]	
62	[illegible]	[illegible]		[illegible]	[illegible]	
64	[illegible]	[illegible]		[illegible]	[illegible]	
66	[illegible]	[illegible]		[illegible]	[illegible]	
68	[illegible]	[illegible]		[illegible]	[illegible]	
70	[illegible]	[illegible]		[illegible]	[illegible]	
72	[illegible]	[illegible]		[illegible]	[illegible]	
74	[illegible]	[illegible]		[illegible]	[illegible]	
76	[illegible]	[illegible]		[illegible]	[illegible]	
78	[illegible]	[illegible]		[illegible]	[illegible]	
80	[illegible]	[illegible]		[illegible]	[illegible]	
82	[illegible]	[illegible]		[illegible]	[illegible]	
84	[illegible]	[illegible]		[illegible]	[illegible]	
86	[illegible]	[illegible]		[illegible]	[illegible]	
88	[illegible]	[illegible]		[illegible]	[illegible]	
90	[illegible]	[illegible]		[illegible]	[illegible]	
92	[illegible]	[illegible]		[illegible]	[illegible]	
94	[illegible]	[illegible]		[illegible]	[illegible]	
96	[illegible]	[illegible]		[illegible]	[illegible]	
98	[illegible]	[illegible]		[illegible]	6,300	
100	[illegible]	[illegible]		[illegible]	6,300	
105	[illegible]	[illegible]		[illegible]	6,310	
110	[illegible]	[illegible]		[illegible]	6,300	
115	[illegible]	[illegible]		[illegible]	[illegible]	
120	[illegible]	[illegible]		[illegible]	[illegible]	
125	[illegible]	[illegible]		[illegible]	[illegible]	
130	[illegible]	[illegible]		[illegible]	[illegible]	
135	[illegible]	[illegible]		[illegible]	[illegible]	
140	[illegible]	[illegible]		[illegible]	[illegible]	
145	[illegible]	[illegible]		[illegible]	[illegible]	
150	[illegible]	[illegible]		[illegible]	[illegible]	
160	[illegible]	[illegible]		[illegible]	[illegible]	
170	[illegible]	[illegible]		[illegible]	[illegible]	
180	[illegible]	[illegible]		[illegible]	[illegible]	
190	[illegible]	[illegible]		[illegible]	[illegible]	
200	[illegible]	[illegible]		[illegible]	[illegible]	

TABLE 2.

Stress in Compression Members; l = length in feet, r = least radius of gyration in inches. Clause 142.

$\frac{l}{r}$	Flat ends.	One flat and one pin end.	Pin at both ends.	$\frac{l}{r}$	Flat ends.	One flat and one pin end.	Pin at both ends.	$\frac{l}{r}$	Flat ends.	One flat and one pin end.	Pin at both ends.
3·0	14930	14440	13990	6·4	12060	10730	9670	9·6	9210	7600	6470
3·2	14790	14250	13750	6·6	11870	10510	9430	9·8	9060	7430	6310
3·4	14650	14050	13500	6·8	11690	10290	9200	10·0	8890	7270	6150
3·6	14500	13850	13250	7·0	11500	10080	8970	10·2	8730	7120	6010
3·8	14350	13640	13000	7·2	11310	9860	8750	10·4	8570	6970	5860
4·0	14190	13420	12740	7·4	11130	9650	8530	10·6	8430	6820	5720
4·2	14020	13210	12490	7·6	11050	9450	8320	10·8	8290	6670	5580
4·4	13860	12990	12230	7·8	10760	9250	8110	11·0	8130	6530	5450
4·6	13690	12760	11960	8·0	10580	9050	7910	11·2	7990	6390	5320
4·8	13510	12530	11700	8·2	10400	8860	7710	11·4	7850	6250	5200
5·0	13330	12310	11430	8·4	10230	8660	7520	11·6	7710	6120	5080
5·2	13160	12080	11170	8·6	10060	8480	7330	11·8	7570	5990	4960
5·4	12980	11850	10910	8·8	9890	8300	7150	12·0	7440	5870	4840
5·6	12800	11620	10660	9·0	9710	8110	6970	12·2	7310	5740	4730
5·8	12610	11400	10400	9·2	9540	7940	6800	12·4	7180	5620	4620
6·0	12430	11170	10150	9·4	9360	7770	6630	12·6	7060	5510	4520
6·2	12240	10960	9910								

TABLE 3.

Maximum Bending Moments on Pins with Extreme Fibre Stress of 25,000 pounds per Square Inch.

Diam. of Pin in Inches.	Area of Pin in Square Inches.	Moments in Inch Pounds.	Diam. of Pin in Inches.	Area of Pin in Square Inches.	Moments in Inch Pounds.	Diam. of Pin in Inches.	Area of Pin in Square Inches.	Moments in Inch Pounds.	Diam. of Pin in Inches.	Area of Pin in Square Inches.	Moments in Inch Pounds.
2	3.142	19600	4¼	14.186	188400	6½	33.183	674000	8¾	60.132	1644200
2⅛	3.547	23600	4⅜	15.033	205500	6⅝	34.472	713700	8⅞	61.862	1715700
2¼	3.976	28000	4½	15.904	223700	6¾	35.785	754800	9	63.617	1789200
2⅜	4.430	32900	4⅝	16.800	242800	6⅞	37.122	797600	9⅛	65.397	1864800
2½	4.909	38400	4¾	17.721	263000	7	38.485	841800	9¼	67.201	1942500
2⅝	5.412	44400	4⅞	18.665	284400	7⅛	39.871	887800	9⅜	69.029	2022300
2¾	5.940	51000	5	19.635	306800	7¼	41.282	935300	9½	70.882	2104300
2⅞	6.492	58300	5⅛	20.629	330400	7⅜	42.718	984500	9⅝	72.760	2188500
3	7.069	66300	5¼	21.648	355200	7½	44.179	1035400	9¾	74.662	2274900
3⅛	7.670	74900	5⅜	22.691	381100	7⅝	45.664	1088100	9⅞	76.589	2363500
3¼	8.296	84300	5½	23.758	408300	7¾	47.173	1142500	10	78.54	2454400
3⅜	8.946	94400	5⅝	24.850	436800	7⅞	48.707	1198700	10¼	82.52	2643100
3½	9.621	105200	5¾	25.967	466600	8	50.265	1256600	10½	86.59	2841200
3⅝	10.321	116900	5⅞	27.109	497700	8⅛	51.849	1316500	10¾	90.76	3049100
3¾	11.045	129400	6	28.274	530100	8¼	53.456	1378200	11	95.03	3266800
3⅞	11.793	142800	6⅛	29.465	564000	8⅜	55.088	1441800	11¼	99.40	3494600
4	12.566	157100	6¼	30.680	599200	8½	56.745	1507300	11½	103.87	3732800
4⅛	13.364	172300	6⅜	31.919	635900	8⅝	58.426	1574800	12	113.10	4241200

TABLE 4.

Shearing and Bearing Value of Rivets in Pounds, Highway Bridges

HIGHWAY BRIDGES.

Dia. of Rivet.	Single Shear of 13750	SHOP RIVETS BEARING AT 27500 PER SQUARE INCH.												
		1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
3/8	1520	2575	3220	3860										
1/2	2700	3440	4300	5160	6015	6875								
5/8	4220	4300	5375	6450	7520	8600	9675	10740						
3/4	6075	5160	6450	7740	9025	10310	11600	12890	14175	15475				
7/8	8270	6010	7520	9025	10540	12040	13530	15040	16550	18050	19550	21060	22560	
1	10800	6875	8600	10310	12030	13750	15475	17190	18910	20625	22350	24060	25780	27500

Dia. of Rivet.	Single Shear of 11000	HAND DRIVEN FIELD RIVETS BEARING AT 22000 PER SQUARE INCH.												
		1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
3/8	1210	2060	2580	3090										
1/2	2160	2750	3440	4130	4820	5500								
5/8	3370	3440	4300	5160	6020	6880	7740	8600						
3/4	4860	4130	5160	6190	7220	8250	9280	10320	11340	12380				
7/8	6610	4810	6020	7220	8430	9620	10840	12040	13240	14440	15640	16840	18040	
1	8640	5500	6880	8250	9620	11000	12380	13750	15130	16500	17880	19250	20630	22000

Dia. of Rivet.	Single Shear of 12500	MACHINE DRIVEN FIELD RIVETS BEARING AT 25000 PER SQUARE INCH.												
		1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
3/8	1380	2350	2930	3520										
1/2	2455	3130	3910	4690	5470	6250								
5/8	3835	3910	4880	5860	6840	7810	8790	9770						
3/4	5520	4690	5860	7030	8210	9380	10550	11720	12890	14060				
7/8	7515	5470	6840	8210	9580	10940	12310	13670	15040	16410	17770	19140	20510	
1	12500	6250	7820	9380	10940	12500	14060	15630	17190	18750	20320	21880	23440	25000

TABLE 8.

Shearing and Bearing Value of Rivets in Pounds, Railway Bridges.

RAILWAY BRIDGES.

[illegible] PER SQUARE INCH.

Dia. of Rivet.	[illegible]	¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾	13/16	⅞	15/16	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] PER SQUARE INCH.

Dia. of Rivet.	[illegible]	¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾	13/16	⅞	15/16	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] PER SQUARE INCH.

Dia. of Rivet.	[illegible]	¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾	13/16	⅞	15/16	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 6.

Deductions for Rivet Holes.

Size of Rivet.	No. of Holes.	Thickness of Plate.							
		$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$
⅞" rivet, 1" hole.	1	·3125	·375	·4375	0·5	·5625	·625	·6875	·75
	2	·625	·75	·875	1·0	1·125	1·25	1·375	1·5
	3	·9375	1·125	1·3125	1·5	1·6875	1·875	2·063	2·25
	4	1·25	1·5	1·75	2·0	2·25	2·5	2·75	3·0
¾" rivet, ⅞" hole.	1	·273	·328	·383	·438	·492	·545	·60	·656
	2	·547	·656	·766	·875	·984	1·09	1·20	1·31
	3	·82	·984	1·149	1·313	1·476	1·635	1·80	1·965
	4	1·09	1·31	1·53	1·75	1·97	2·19	2·41	2·63

TABLE 7

Table for Proportioning Gear and Rack Teeth

$$W = S\,P\,F\,Y$$

in which W is the load transmitted by the teeth, in pounds; S is the safe working stress of the material, taken at 8,000 lbs. for cast iron, and 20,000 lbs. for cast steel per square inch, when the working speed is 100 ft. or less per minute; P = pitch; F = face, in inches; Y = a factor depending on the form of the tooth, whose value for different cases is given in the following table:—

No. of Teeth.	Factor for Strength, Y.			No. of Teeth.	Factor for Strength, Y.		
	Involute 20° Obliquity.	Involute 15° and Cycloidal.	Radial Flanks.		Involute 20° Obliquity.	Involute 15° and Cycloidal.	Radial Flanks.
12	·078	·067	·052	27	·111	·100	·064
13	·083	·070	·053	30	·114	·102	·065
14	·088	·072	·054	34	·118	·104	·066
15	·092	·075	·055	38	·122	·107	·067
16	·094	·077	·056	43	·126	·110	·068
17	·096	·080	·057	50	·130	·112	·069
18	·098	·083	·058	60	·134	·114	·070
19	·100	·087	·059	75	·138	·116	·071
20	·102	·090	·060	100	·142	·118	·072
21	·104	·092	·061	150	·146	·120	·073
23	·106	·094	·062	300	·150	·122	·074
25	·108	·097	·063	Rack.	·154	·124	·075

Allowable Working Stress, S, for different speeds.

—	Speed of Teeth in ft. per minute.							
	100 or less.	200	300	600	900	1,200	1,800	2,400
Cast Iron	8,000	6,000	4,800	4,000	3,000	2,400	2,000	1,700
Steel	20,000	15,000	12,000	10,000	7,500	6,000	5,000	4,300

All gears having a pitch line speed exceeding 500 ft. per min. shall be machine cut.

TABLE 8.

SIZES OF RAILROAD BRIDGE TIES.

CANADIAN WHITE AND RED PINE.						LONG LEAF YELLOW PINE AND DOUGLAS FIR.					
Width x Depth	Moment of Resistance S	Allowable Span in ft.				Width x Depth	Moment of Resistance	Allowable Span in ft.			
		Class heavy	Class I.	Class II.	Class III.			Class heavy	Class I.	Class II.	Class III.
8 x 8	85·3	.....	....	......	6	8 x 8	85·3	.....	....	....	7
8 x 10	133	....	....	7	7	8 x 10	133	7	7	7	8
8 x 12	192	7	7	7	8	8 x 12	192	8	8	9	9
10 x 8	107	......	......	......	6	10 x 8	107	7	7	7	7
10 x 10	166	7	7	7	7	10 x 10	166	8	8	8	9
10 x 12	240	7	8	8	9	10 x 12	240	9	9	10	11
10 x 14	327	9	9	9	10	10 x 14	327	10	11	12	13
10 x 16	427	10	10	11	12	10 x 16	427	12	13	14	15
12 x 8	128	......	......	......	7	12 x 8	128	7	7	7	8
12 x 10	200	7	7	7	8	12 x 10	200	8	8	9	10
12 x 12	288	8	8	9	9	12 x 12	288	10	10	11	12
12 x 14	392	9	10	10	11	12 x 14	392	12	12	13	14
12 x 16	512	11	11	12	13	12 x 16	512	14	15	16	17
12 x 18	648	12	12	14	14	12 x 18	648	16	17	18	18
12 x 20	800	14	15	16	17	12 x 20	800	18	18		
12 x 22	968	16	17	18	...	12 x 22	968	....			
14 x 8	149	.....	6	7	7	14 x 8	149	7	7	8	8
14 x 10	233	7	7	8	8	14 x 10	233	9	9	10	10
14 x 12	336	9	9	9	10	14 x 12	336	11	11	12	13
14 x 14	457	10	10	11	12	14 x 14	457	13	14	15	16
14 x 16	597	12	12	13	14	14 x 16	597	15	16	18	
14 x 18	756	14	14	16	16	14 x 18	756	18	....		
14 x 20	933	16	17	18	—	14 x 20	933	....	—	—	—

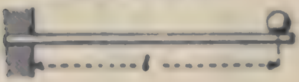
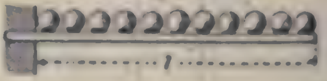
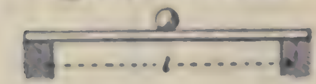
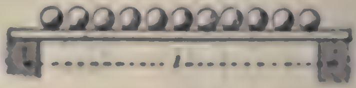
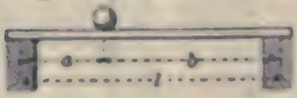
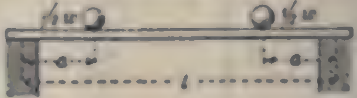
TABLE 9.

DECIMALS of an inch of fractions of inches, columns 1 and 2; decimals of a foot for inches and fractions, columns 2 and 3.

[illegible]

TABLE 10

BENDING MOMENTS AND DEFLECTIONS OF BEAMS, UNDER VARIOUS SYSTEMS OF LOADING.

W—total load. l=length of beam.	I—moment of Inertia. E—modulus of elasticity.
(1.) Beam fixed at one end and loaded at the other.  Maximum bending moment at point of support—Wl. Maximum shear at points of support—W. Deflection—$\frac{Wl^3}{3EI}$	(2.) Beam fixed at one end and uniformly loaded.  Maximum bending moment at point of support—$\frac{Wl}{2}$ Maximum shear at point of support—W. Deflection—$\frac{Wl^3}{8EI}$
(3.) Beam supported at both ends, single load in the middle.  Maximum bending moment at middle of beam—$\frac{Wl}{4}$ Maximum shear at points of support—½W Deflection—$\frac{Wl^3}{48EI}$	(4.) Beam supported at both ends and uniformly loaded.  Maximum bending moment at middle of beam—$\frac{Wl}{8}$ Maximum shear at points of support—½W. Deflection—$\frac{Wl^3}{76.8EI}$
(5.) Beam supported at both ends, single unsymmetrical load.  Maximum bending moment under load—$\frac{Wab}{l}$ Maximum shears: at support near a—$\frac{Wb}{l}$; at other support—$\frac{Wa}{l}$ Max. Deflec.—$\frac{Wab(2l-a)}{9EIl}\cdot\sqrt{\frac{1}{3}a(2l-a)}$.	(6.) Beam supported at both ends, two symmetrical loads.  Maximum bending moment between loads—½Wa. Maximum shear between load and nearer support—½W. Max. Deflection—$\frac{Wa}{48EI}(3l^2-4a^2)$

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